PLANT PATHOLOGY

A RECORD OF CURRENT WORK ON PLANT DISEASES AND PESTS

Published quarterly for the
Ministry of Agriculture, Fisheries and Food
Plant Pathology Laboratory
Harpenden, Herts

VOLUME 7, No. 2
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LOSSES CAUSED BY POTATO BLIGHT IN ENGLAND AND WALES

Contribution from the Conference of Plant Pathologists, National Agricultural Advisory Service, compiled by E. C. Large, of the Plant Pathology Laboratory, Harpenden, Herts.

SINCE 1950, systematic surveys of the incidence of blight on the haulm of maincrop potatoes have been carried out each year in all regions of England and Wales by plant pathologists and district advisory officers of the N.A.A.S., in collaboration with the Plant Pathology Laboratory at Harpenden. These surveys, as already reported in this JOURNAL (Large 1953, 1956), have been made for the dual purpose of developing blight forecasting and providing information for the assessment of blight losses due to premature defoliation. Since 1952, the Potato Division of the Ministry of Food, and more recently the Potato Marketing Board, have also collaborated with the Plant Pathology Laboratory, by the systematic recording of blight in the tubers—and other particulars concerning potato blight—throughout their crop-check weighings on some 2,000 potato crops in England and Wales each year. A critical study has now been made of all the survey information from both sources in the light of sequences of spraying trials, and estimates are here presented of the losses caused not only by premature defoliation, but also by tuber infection in England and Wales over the ten-year period, 1947 to 1956.

LOSSES IN UNSPRAYED CROPS DUE TO PREMATURE DEFOLIATION

With the progressive decay of the haulm during a blight attack, a point is reached sooner or later at which tuber production stops. Throughout the surveys in England and Wales, this point is taken, on average, as the 75 per cent blight stage as assessed by the B.M.S. key. For the maincrops in England and Wales, which, in the absence of blight, normally die down towards the end of September, the relationship between 75 per cent date and loss of potential crop is estimated to be as shown in Table 1.

TABLE 1

Mean Loss of Potential Crop in Relation to Blight on Haulm

	75 per cent Blight on Haulm				
	End of July	*Mid-August*	*End of August*	*Mid-September*	*End of September*
Mean loss of potential crop *per cent*	50	28	13	4	0
Yield in tons per acre					
10-ton potential crop ..	5·0	7·2	8·7	9·6	10
15-ton potential crop ..	7·5	10·8	13·0	14·4	15
	Yields for other crop levels *pro rata*.				

The mean figures in Table 1, originally estimated by Large (1952) from data for 60 crops of Majestic over the years 1940–45 (Doncaster and Gregory, 1948)

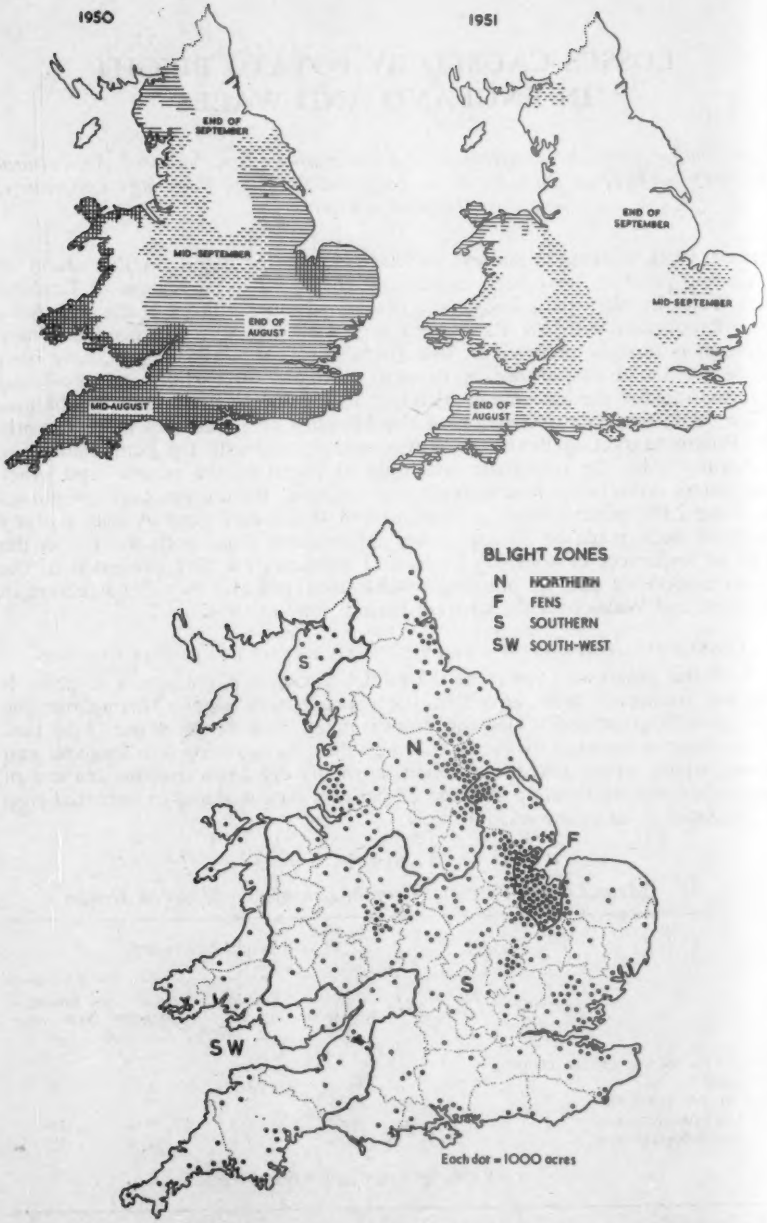

Fig. 1. Blight Zones, and approximate distribution of potato maincrops in England and Wales. *Above:* maps showing mean dates at which the 75 per cent blight stage on the haulm was reached in a typical blight-year (1950) and in one of the other years (1951).

have since been checked against the results of spraying trials carried out over a number of years in Devon and Cornwall by Beaumont and Large (1944, and other data); in Yorkshire by Beaumont, Bant and Storey (1953); in the area round the Wash by Large, Taylor, Storey and Yule (1954), and in the West Midlands by Rosser (1957). These checks, and others in progress, have confirmed that although the losses in individual crops vary considerably about the means, the figures in Table 1 may fairly be taken for the estimation of regional losses over a number of years, not only in Majestic, but also for King Edward and most other maincrop varieties.

The mean date at which the 75 per cent blight stage is reached varies very greatly according to region and season. Survey maps, zoning the country according to this date, have already been published in this JOURNAL for each of the years 1950 to 1955 (Large, 1956). Maps for a fairly typical "blight year" (1950) and for a fairly typical "other year" (1951) are here reproduced in Fig. 1. From a consideration of all the zoning maps, it has been found that those for the "blight years" (1950, 1953, 1954, 1956 and also 1957) show a fairly constant pattern. The pattern for the "other years" is very different, but also fairly constant. Thus it becomes possible to divide the country into four main blight zones for loss-estimation purposes, as shown on the lower map in Fig. 1, namely:

SOUTH-WEST ZONE

A south-western and west-coastal belt including the potato growing areas in Cornwall, Devon, Somerset, Gloucester, Monmouth, Glamorgan, Carmarthen, Pembroke, Cardigan, Merioneth, Caernarvon and Anglesey.

FEN ZONE

An area round the Wash, roughly equivalent in acreage to that of the Isle of Ely and the Holland Division of Lincolnshire but extending into Hunts. and West Norfolk.

SOUTHERN ZONE

All the rest of the country south of Denbigh, Cheshire, Derby and Notts., but including the Kesteven and Lindsey Divisions of Lincolnshire, and also the northern county, Cumberland, where the epidemics are similar to those in the south.

NORTHERN ZONE

Northumberland, Durham, Yorkshire, Westmorland, Lancashire, Denbigh, Flint, Cheshire, Derby and Nottinghamshire.

The approximate distribution of maincrops (including second earlies) based on the official statistics for 1954 is shown on the zoning map to indicate the relative importance of each zone in the country's maincrop production.

With this zoning, and taking in 1947 and 1949 which were dry years, and 1948 which was a "blight year", an analysis has now been made of the mean 75 per cent dates in unsprayed crops*, and the corresponding defoliation losses that would have occurred in the total absence of protective spraying, zone by zone, and for the country as a whole, over a ten-year period. This basic information is presented in Table 2.

Table 2 shows that if all the maincrop potatoes in the country had been left unsprayed over the ten years, the mean annual loss due to premature defoliation by blight would have amounted to about 8 per cent. Eight per cent, that is to say, of the total yield that would have been obtained had blight been entirely absent. But in the South-west zone where every year was a "blight year" (75 per cent stage by or before the end of August), the mean loss would have been about 20 per cent; in the Fen zone, with six "blight years" in ten, about

* Blight does not of course reach the 75 per cent stage on all the unsprayed crops in a zone at precisely the same time. There are differences from crop to crop due to variety, time of planting, local topography and many other factors. A spread of about a week on either side of the mean date is common, and is to be understood in reading the table.

14 per cent; in the Southern zone, with five "blight years" in ten, and 75 per cent dates rather later, 7 per cent; and in the Northern zone, with 75 per cent dates always in September, only about 2 per cent. In the five "blight years" for the large Southern zone, the mean defoliation loss for England and Wales as a whole would have been about 16 per cent, and in the five "other years" about 2 per cent.

TABLE 2

Estimated Defoliation Losses due to Potato Blight if all Maincrops in England and Wales had been left Unsprayed over a Ten-year Period (1947–56)

Zone	Maincrop Acreage per cent of Total	Number of Years in Ten in which the 75 per cent Blight Stage was Reached by				Mean Loss per annum over the Ten Years	
		Mid-Aug *28 per cent Loss*	End Aug *13 per cent Loss*	Mid-Sept *4 per cent Loss*	End Sept *No Loss*	to Zone *per cent*	to Whole Country *per cent*
South-west	8	5	5	0	0	20	1·7
Fens	13	4	2	1	3	14	1·8
Southern	51	0	5	2	3	7	3·7
Northern	28	0	0	5	5	2	0·6
England and Wales ..							7·8

REDUCTION OF DEFOLIATION LOSSES BY PROTECTIVE SPRAYING

Protective spraying very rarely saves the whole of the defoliation loss due to blight. The gain from spraying is, moreover, reduced by damage to the crop from the passage of the sprayer wheels, and in hot dry seasons when there is little blight, spraying may sometimes cause loss not only by wheel damage but by copper injury to the foliage.

Detailed study of the results of all the spraying trials already cited has shown that a good practical result of *efficient* commercial spraying, with two well-timed applications in general, and three where needed, is to give the equivalent of about two weeks prolongation of growth when the 75 per cent stage on the unsprayed crop is reached during August or in the first few days of September. And this gain can be obtained notwithstanding the wheel damage. Loss by wheel damage is a very variable factor that may amount to 10 per cent of the potential crop, or even more, when the width of the spraying boom is narrow, and the growth of the haulm is lush and early in sprawling (Large, Taylor, Storey and Yule, 1954), but for the purpose of the present estimates a very moderate mean figure of only 3 per cent is taken. Where the 75 per cent blight stage is not reached until mid-September the gain from spraying is generally almost entirely offset by the loss from wheel damage. The mean loss from copper injury to the foliage in hot dry seasons cannot yet be assessed with any certainty; although considerable in some crops, its mean effect should not be exaggerated. It is therefore put here at only 3 per cent and it is deducted only in those very dry seasons when blight does not reach the 75 per cent stage before the end of September, and then only in the Southern, Fen and South-west zones—not in the Northern. With these bases of reckoning the mean gains and losses from protective spraying, according to the date at which the 75 per cent stage is reached on the unsprayed crop, are as shown in Table 3.

TABLE 3

Estimated Mean Gains and Losses from Efficient Commercial Spraying According to the Date by which the 75 per cent Blight Stage is Reached on the Unsprayed Maincrops

75 per cent Blight on Unsprayed Haulm by:	Percentages of Potential Crop*					
	Yield of Unsprayed	Yield of Sprayed	Net Gain from Spraying	Unrecovered Loss		
				by Wheel Damage	*by Blight*	*by Copper Injury*
Mid-August	72	86	14	3	11	—
End of August	87	95	8	3	2	—
Mid-September	96	97	1	3	—	—
End of September						
Northern Zone	100	97	− 3	3	—	—
Elsewhere	100	94	− 6	3	—	3

* Potential crop = unsprayed crop in absence of blight.

Thus under the conditions of a severe blight epidemic with 75 per cent stage on the haulm about mid-August, and a potential crop of 10 tons per acre, the unsprayed crop would be about 7·2 tons per acre and the gain from spraying about 1·4 tons per acre. With a 15-ton potential crop (a common level in trials and in the better crops in blight years) the unsprayed yield would be one-and-a-half times 7·2 tons, that is 10·8 tons, and the gain from spraying about 2·1 tons —and *pro rata*, throughout the table.

Records obtained for the representative samples of some two thousand crops each year in the crop-check weighings have indicated that over the period 1953–56 the proportion of the maincrops which received *any* protective treatment was about 55 per cent in the Fen zone, 40 per cent in the Southern zone, 20 per cent in the South-west zone, and 5 per cent in the Northern zone, making about 30 per cent for England and Wales as a whole. There was relatively little variation from year to year, and the proportion of sprayed crops in the King Edward was about twice that in the Majestic and other varieties.

Assuming that the same proportion of the crops had been sprayed each year over the ten-year period, 1947–56, and substituting in Table 2 the mean net gains calculated in Table 3, an estimate can be made for the mean gain from spraying in each blight zone, and in the country as a whole, over the ten years (Table 4).

Thus, if routine spraying was done every year on the proportion of the acreage which received *any* protective treatment in the years 1953–56, and all this was "efficient" spraying, the mean gain over a ten-year period would amount to about 1 per cent of the total potential maincrop yield for the country as a whole. This would represent a saving of about one-eighth of the total defoliation loss due to blight (Table 2), and, in round figures, it would make a difference of rather less than 0·1 tons to the average maincrop potato yield for England and Wales over the ten-year period.

A similar analysis to that in Table 4 shows that the same amount of "efficient" spraying would result in an average national gain of about 0·3 tons per acre in the five years which can be called "blight years", and an average national loss of about 0·1 tons per acre in the "other years".

TABLE 4

Estimated Maximum Gain from Routine Spraying, as Percentage of Potential Crop, over a Ten-year Period

Zone	Maincrop Acreage per cent of total	Mean Net Gain from Spraying *per cent*	Acreage Sprayed *per cent*	Mean Gain for Zone *per cent*	Contribution to National Gain *per cent*
South-west	8	11·0	20	2·20	0·18
Fens	13	5·5	55	3·02	0·39
Southern	51	2·4	40	0·96	0·50
Northern	28	− 1·0	5	− 0·01	0·00
England and Wales					1·07

The economic significance of these figures cannot be seen without taking into account the general level of yields in the "blight years" and the "other years". In general, the abundant rainfall during July and August in the "blight years" tends to raise the average yield of potatoes very substantially despite the blight; and the dry, or drought, conditions in the "other years" tend to depress it. The following figures from the official statistics for 1947 to 1956 are average yields for all varieties (earlies as well as maincrops) in England and Wales, but they serve well enough as an index of crop levels:

Blight years					Other years				
1948	1950	1953	1954	1956	1947	1949	1951	1952	1955
7·6	7·7	8·7	7·9	8·3	5·8	6·6	7·9	7·9	7·3
Mean: 8·0 tons per acre					Mean: 7·1 tons per acre				

A national gain of 0·3 tons per acre from efficient spraying in a "blight year" would be substantial, but in such years as 1953 and 1956 it could cause embarrassment by adding to a surplus. (0·3 tons per acre with maincrop acreage at about half a million represents some 150,000 tons). The loss from spraying in the years with little blight, though only of the order of 0·1 tons per acre, could have quite a serious effect by reducing potato supplies, to the extent of 50,000 tons or more, when the crop is already light from lack of rain.

Despite these national considerations, the gain from spraying achieved by individual growers, in particular districts and seasons, and on the better crops and more valuable varieties, can often be very considerable. For example, with potatoes at £11 per ton, a gain of only 0·4 tons per acre would pay for two contract sprayings at 45*s.* per acre, and in a blight year in some zones (see Tables 2 and 3) such sprayings, if well-timed and done thoroughly, can often give an increase of 1 or even 2 tons for the outlay.

The surveys have shown that there can rarely be a year in which protective spraying is worth while in the Northern zone. It can be profitable on the better crops in the Southern zone in five years out of ten. In the Fen zone it can be profitable six years out of ten, and is just economic as a routine measure on King Edward. In the South-west zone it can be profitable on all maincrops almost every year, but in this zone the potato acreage is relatively small—apart from the earlies, on which spraying is quite exceptional.

LOSSES DUE TO BLIGHT IN THE TUBERS

Losses due to blight in the tubers vary greatly from crop to crop in England and Wales. Even in a bad year for tuber infection more than half the crops suffer little or no loss from this cause. But against this there is always a small proportion of the crops in which there is heavy loss, and this tends to colour the picture, and to give the impression that the overall loss from blight in tubers must be much greater than is in fact the case.

The frequency distribution of different levels of loss due to blight in tubers is well exemplified in Fig. 2 for the crop-check survey in 1954. In this "blight year" 57 per cent of the 2,109 crops surveyed in England and Wales had virtually no blighted tubers when examined shortly before lifting; about 25 per cent had 1 to 5 cwt per acre; about 8 per cent had 5 to 10 cwt, and there were sharply decreasing percentages at higher rates. Although the mean for the whole country was only $3\frac{1}{2}$ cwt per acre, there were over 100 crops among the 2,109 in which the loss was over a ton per acre, and two in which it was over 3 tons.

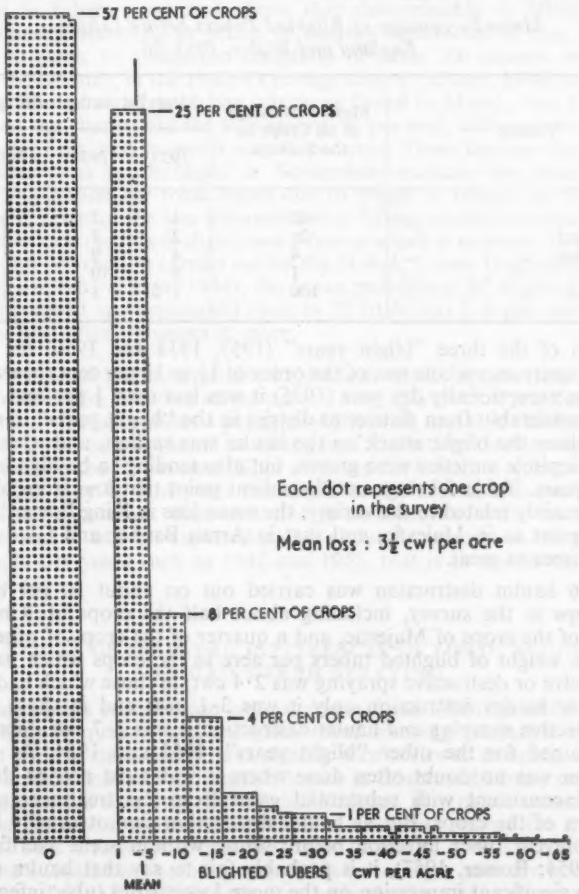
57 PER CENT OF CROPS
25 PER CENT OF CROPS
Each dot represents one crop in the survey
Mean loss : 3½ cwt per acre
8 PER CENT OF CROPS
4 PER CENT OF CROPS
1 PER CENT OF CROPS
0
1 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50 -55 -60 -65
MEAN
BLIGHTED TUBERS CWT PER ACRE

Fig. 2. Frequency of different levels of blight in tubers before lifting in a survey of 2,109 crops in England and Wales, 1954.

Losses from blight in the tubers comprise (*a*) losses caused by infection in the ground before lifting, and (*b*) losses caused by infection *at* lifting and not apparent until after a period in store. Of these, the first is a general loss that can occur to a greater or lesser extent wherever there is any blight on the haulm during the season, and the second is an occasional loss, materially affecting only those crops in which the haulm has not been dead for ten days to a fortnight before lifting.

Good survey information on the losses due to infection before lifting has been provided by weighing the blighted tubers found in samplings, made shortly before lifting, on over 8,000 crops in the crop-check surveys over the years 1953 to 1956. Table 5 shows the yearly mean losses, for England and Wales, expressed as percentages of total crop on a 1½ inch riddle, for all varieties, and also for four individual varieties of special interest.

TABLE 5

Mean Percentage of Blighted Tubers before Lifting
England and Wales, 1953–56

Variety	Mean Percentage of all Crops in the Surveys	Mean Percentage of Blighted Tubers			
		1953	*1954*	*1955*	*1956*
Majestic	47	1	1	<½	1
King Edward	26	2	3	<½	2
Arran Banner	4	4	9	1	11
Gladstone	1	8	10	<½	17
All Varieties	100	1·5	1·7	<½	1·7

In each of the three "blight years" (1953, 1954 and 1956) the mean loss for the country as a whole was of the order of 1½ to 1¾ per cent (3½ cwt per acre) and in the exceptionally dry year (1955) it was less than ½ per cent. The losses varied considerably from district to district in the "blight years", tending to be highest where the blight attack on the haulm was earliest, and where the more tuber-susceptible varieties were grown, but also tending to be high in the north in some years. Table 5 brings out the salient point that loss from blight in the tubers is mainly related to the variety: the mean loss in King Edward being over twice as great as in Majestic, and that in Arran Banner and Gladstone being over six times as great.

In 1956 haulm destruction was carried out on about 30 per cent of the 2,057 crops in the survey, including about half the crops of King Edward, one-fifth of the crops of Majestic, and a quarter of the crops of other varieties. The mean weight of blighted tubers per acre in the crops which had received no protective or destructive spraying was 2·4 cwt; in those which had protective spraying *or* haulm destruction only it was 3·1 cwt; and in those which had both protective spraying *and* haulm destruction it was 2·7 cwt. Similar figures were obtained for the other "blight years", 1953 and 1954. As the haulm destruction was no doubt often done where it was most needed these figures are not inconsistent with substantial gains from the treatment on a small proportion of the crops. But as haulm destruction cannot usually be done in time to prevent tuber infection before lifting without some sacrifice of crop (Large, 1954; Rosser, 1957), it is probably fair to say that haulm destruction makes no significant impression on the mean losses from tuber infection *before lifting* in England and Wales as a whole.

Haulm destruction can greatly reduce losses from tuber infection *at lifting* where the crop would otherwise be lifted in the presence of surviving haulm on which the blight fungus is sporing. But this is not the usual state of affairs among the maincrops in England and Wales, so many of which are not lifted until October. Observations made in the crop-check surveys in 1953–56 showed that, in the "blight years", even if no haulm destruction had been done, two-thirds of the crops would have had their haulm quite dead before lifting, and in the rest there was little growth left. The actual percentages of the crops falling into each of three categories for state of haulm some days before lifting were:

	1953	*1954*	*1955*	*1956*
Haulm destroyed	17	22	10	30
Haulm dead	84	85	56	94
Little growth left	16	15	44	6

There is, so far, comparatively little direct survey information on the loss from blight in tubers, over and above that determinable at lifting, due to infection actually occurring at lifting or passing undetected at that time and developing in store. In systematic samplings of some 700 clamps, well distributed over the country, in the 1942–43 storage season (Moore, 1948) the average total loss attributed to blight in the tubers, as found in March, was 3 per cent. In only 38 of the clamps did the loss exceed 10 per cent, although in several it reached 30 per cent, and in one it was 43 per cent. These figures—for a season in which there was much blight in September—indicate the same kind of frequency distribution for total losses due to blight in tubers, as that shown in Fig. 2 for the part of the loss determinable at lifting, namely a preponderance of clamps in which the loss is slight, and a few in which it is heavy. In a series of trials of haulm destruction carried out by the N.A.A.S. over England and Wales in the years 1951–53 (Large, 1954), the mean percentage of blighted tubers in all the acid-sprayed and unsprayed plots in 31 trials was 1·8 per cent at lifting and 2·5 per cent after six weeks in store.

From a review of all the available evidence it would appear that the mean total loss from blight infection of the tubers, over all varieties, and for England and Wales as a whole, is about 3 per cent of the crop, and that this loss is made up of about 2 per cent apparent at lifting and 1 per cent developing in store. As years in which the 75 per cent blight stage on the foliage is not reached until mid-September may be bad years for blight in the tubers, it is probable that this loss is more constant than that due to reduction of yield by premature defoliation, and it can be expected to be about 3 per cent in all except the outstandingly dry years such as 1947 and 1955, that is to say in eight or nine years out of ten.

INTERRELATIONS OF SEASONAL DIFFERENCES IN YIELD, BLIGHT LOSSES AND GAINS FROM SPRAYING

The whole of this contribution is in summary form. The regional distribution of losses, their frequency, and the gains from spraying attainable by growers in different parts of the country have already been reviewed as briefly as possible under the several heads of defoliation losses in unsprayed crops, reduction of losses by protective spraying, and blight in tubers. It remains to assemble the parts of the jig-saw of losses and gains into one clear picture for the country as a whole. This is attempted in a final table (Table 6) in which confusing percentages are swept away, actual mean yields in tons per acre are given by way of example, and all gain and loss estimates, arrived at by means already explained, are rounded off.

TABLE 6

Illustrative Analysis of Yields, Losses and Gains over a Ten-year Period, Based on Experience in 1947–56, with Assumptions as Stated

	Averages for England and Wales Tons per acre		
	Blight years	*Other years*	*All years*
Potential yield	9·6	7·7	8·6
Defoliation loss by blight if all crops were left unsprayed	− 1·6	− 0·2	− 0·8
Reduction of this loss by efficient spraying of 30 per cent of the crops	+ 0·3	− 0·1	+ 0·1
Loss from blight in tubers	− 0·3	− 0·3	− 0·3
Actual yield of sound tubers	8·0	7·1	7·6

Although the "actual" yields in this table are for all varieties and not for maincrops alone, they are of about the right order, and any necessary correction for their general level would not alter the loss estimates within the degree of approximation to which they are given. The table serves to show that blight losses and gains from spraying cannot be considered realistically from a national point of view without taking into account the differences (due to rainfall) between the potential yields in "blight years" and "other years". When this is done, it becomes apparent that the desirability of any increase of spraying in the "blight years" depends on the availability of outlets for surpluses, and that the reduction of losses from unnecessary spraying in the "other years" is of much economic importance. As to blight in the tubers, the mean loss from this cause in the "other years" may be a little less than the 0·3 tons entered in the table, owing to occasional years like 1955, but the relative constancy of this loss from blight in tubers shows the signal benefit that would accrue from any reduction in its general level, as for example, from success in breeding for tuber resistance in quality varieties.

The Conference of Plant Pathologists takes this opportunity of thanking all those officers of the Potato Division of the Ministry of Food and the Potato Marketing Board, and all the district advisory officers of the N.A.A.S., crop recorders, research workers, farmers and others, who have taken part in the potato blight survey work on which these estimates are based.

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OBSERVATIONS ON EELWORM CONTROL IN *NARCISSUS* IN THE ISLES OF SCILLY

by P. R. THOMAS *and* P. WIGGELL

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AND

W. J. MOYSE

formerly National Agricultural Advisory Service, Isles of Scilly

STEM and bulb eelworm, *Ditylenchus dipsaci* (Kühn) Filipjev, sometimes causes serious loss of early daffodils on the Isles of Scilly. Bulbs are generally hot-water treated before planting, but it may be necessary to replant into eelworm-infested soil. The crop usually remains in the ground for three years.

Trials were carried out with soil fumigants and nematicidal surface seals, on St. Mary's in the summer of 1955, in an attempt to disinfect soil and prevent contamination of clean bulbs. Two sites, A and B, were chosen where eelworm had been serious the previous year; A measured 5 yd × 25 yd and B, 5 yd × 40 yd. Bulbs were lifted in June, and treatment took place during the second ploughing in August, the areas being set with clean bulbs again four and eight weeks later respectively. DD Mixture (dichloropropene-dichloropropane) was applied at 100 or 200 gallons per acre from a watering can with regulated flow, and the next furrow was turned over to cover the fumigant. EDB (ethylene dibromide) was mixed with an equal volume of paraffin and applied at the same rates, using the same method as with DD. Fumigant application was followed in both cases by rolling and light harrowing. Surface seals of solubilized xylenol or cresylic acid as 1 per cent preparations (Staniland and Stone, *J. Helminth.*, 1953, **27**, 41–74), were applied at 2 gallons per square yard from a watering can with a fine rose. Water alone at one site and no seal at the other, formed partial controls. Soil temperature 6 inches below the surface was 76° F. at the time the applications were made.

Percentage of Eelworm Infected Plants

Surface Seal	Site A			Site B	
	DD Mixture		Ethylene dibromide	DD Mixture	Ethylene dibromide
	200 gal/ac	*100 gal/ac*	*100 gal/ac*	*200 gal/ac*	*200 gal/ac*
Cresylic acid ..	6	14	1	23	46
Xylenol ..	1	5	0	8	2
Unsealed ..	31	72	4	3	2

In the first year of flowering no eelworm infested plants were found by visual inspection of the treated plots, and laboratory examination of suspected specimens also gave negative results. Adjacent untreated beds showed attacked plants. Inferior growth due to delayed rooting occurred at one site where bulbs were planted eight weeks after application of both fumigants at the 200 gallon rate. The trials were carried out under commercial conditions, and full replication of treatments was not possible; however, since no eelworm-infested plants were found in the treated plots during the first year it seems that re-infestation in the second year came from adjacent untreated beds. This effect of eelworm migration

(73257) A**

into the treated plots is clearly visible in the Table on page 49, which shows the percentage of eelworm-infested plants at the two sites in 1957. From samples taken on adjacent beds at site B it appeared that between 2 and 34 per cent of the bulbs were infested alongside the DD plots while 16–85 per cent were infested next to the EDB treatments. The soil treatments enabled daffodils to be produced commercially for two years, but neither compound prevented reinfestation of eelworm in the second year.

When eelworm patches occur in beds of Narcissus left in the ground for more than a year it is desirable to check their spread. It is necessary to treat an area larger than the visibly infested patch. The bulbs and the eelworms therein may be killed by piercing with a DD gun and injecting the nematicide at maximum setting of the gun. Bulbs treated in this way soon become a putrefying, sodden mass, and no live eelworms have been found in specimens examined. Infested foliage may be destroyed by wetting with a strong preparation of horticultural cresylic acid, one part in 10–15 parts of water; adequate wetting and penetration of the foliage is essential to ensure complete kill of eelworms. Treatment is best carried out as soon as foliage damage appears.

BUTTON TOP MIDGE IN WILLOWS

by C. T. GUILE

National Agricultural Advisory Service, Derby

FOR many years a farmer at North Leverton, Nottinghamshire, has specialized in the cultivation of the almond willow, *Salix triandra* L., for the manufacture of high-quality baskets. In June 1955, three separate fields, or holts, comprising nearly twenty acres of "Wissender" hard rods were found to be severely infested with the midge *Rhabdophaga heterobia* H. Loew.

Damage caused by the larvae is mainly confined to the young leaves of terminal buds. A small loose rosette is formed, the basal leaves of which are often clothed with white woolly hairs (Plate IV, 2). Galling or buttoning of terminal buds results in a slowing down or stoppage of end growth and encourages development of side shoots. Such malformed willow rods are valueless to basket makers.

The female midge oviposits on the terminal and lateral buds. When newly hatched the reddish larvae are only just visible to the unaided eye, but when mature become a brighter orange-red when they can be easily seen within the gall. Normally, pupation occurs within the gall, but larvae can also survive in the soil.

At this holding there are two main broods, midges of the first generation emerging from the end of April until July and overlapping with a second generation on the wing from July to September. Larvae of the first brood produce galls when the willow shoots have sprouted one to three inches from the parent stools. It is from these that second generation adults emerge later in the year to button rods which may have grown three feet or more in height.

Since the entire crop is removed from the holding immediately after harvesting, it seems that the only way in which midge population is maintained is by the activities of tits and other birds which break open the brittle galls in winter, scattering larval cocoons on to the soil. Here the larvae remain quiescent in their cocoons until they pupate shortly before the adult midges emerge.

ECONOMIC ASPECTS AND CONTROL

According to the grower, unsatisfactory yields have been experienced for many years, but when the holding was inundated by the River Trent floodwaters from March to April of 1947, the ensuing crops were much improved. An explanation of the latter could be that winter flooding destroyed larvae in the soil both by drowning and washing them away downstream (Barnes, H. F., *Gall Midges of Economic Importance. Vol VI: Gall Midges of Miscellaneous Crops*, p. 47). From 1952 onwards midge attack increased steadily until, in 1955, the whole crop was severely damaged.

When infestation is negligible the average yield is 7 to 8 tons of top quality rods per acre, selling at £15 to £18 per ton. Under heavy attack the yield is often halved, the poorer quality produce realising less than £5 per ton.

Observations in 1956 indicated that four spray applications of DDT, crude BHC, dieldrin and metasystox at fortnightly intervals from May 9 to July 11 were equally effective in achieving control. Seven applications, by the grower, of three pints of 25 per cent DDT emulsion in ten gallons of water per acre, at weekly intervals from May 4 to mid June, resulted in almost complete control with very little mechanical damage to the crop. No control was achieved on a distant five-acre holt where the first spray was given three weeks later on May 25 (Plate IV, 2).

The same five acre holt, which was badly infested in 1956, was used for trial purposes in 1957. The trial was designed to determine the correct timing and least number of applications of DDT necessary to obtain good control of the first generation midges. Duplicate treatment plots each consisted of nine willow stools. One series of plots received early sprays of four pints of 25 per cent DDT emulsion in 400 gallons of water per acre on May 1, 9, 16, 27; a second series received these sprays as well as a single late spray on June 5; while a third series, which received the four early sprays, also received two late sprays, on June 5 and 17 respectively. After this last date commercial spraying was not practicable as the crop was by then too far advanced in growth to allow passage of machinery.

The first egg batches were noted on May 1 when the shoots had grown two inches or so from the stools, conspicuous buttoning being first evident on May 27. Counts of galled terminal buds were recorded on June 26, none at all being found on the plots which were sprayed at least four times; the results from the plots sprayed less frequently were as follows:

No. of sprays	3 early	2 early	1 early	1 late	Control (unsprayed)
Dates of spraying ..	May 1, 9, 16	May 1, 9	May 1	June 17	—
Percentage buttoning ..	1	12·7	14·0	16·0	19·3

The results indicate that control of the first generation midge attack, with a minimum of three early sprays during the first half of May, results in the unhindered growth of rods which are consequently rendered less liable to infestation by the second generation midge in July.

Commercial spraying by the grower in 1957, employing similar techniques to those of 1956, at ten-day intervals from the end of April to mid June, resulted in complete control and produced a crop surpassing all previous yields and quality.

DDT was effective in reducing damage to hard willow rods when the first applications were given early enough to destroy most of the first generation adults. The date of the first spray was determined by the first signs of sprouting from the stools.

Thanks are due to Dr. M. Cohen for initiating this work, Mr. R. Gair for taking the photographs, Mr. O. M. Brooks for practical help, and to the grower, Mr. W. Brown of North Leverton, for granting trial facilities.

CONTROL OF DAMPING-OFF OF ZINNIAS CAUSED BY *ALTERNARIA ZINNIAE*

by A. BEAUMONT, J. P. CLEARY AND J. H. BANT

National Agricultural Advisory Service, Leeds

DAMPING-OFF and leaf spot diseases of *Zinnia elegans* caused by *Alternaria zinniae* Pape, are widely distributed in Europe and America. In England it was first recorded in 1939 and the disease on the seedlings is undoubtedly much more common than the records would indicate. We have seen it frequently in Yorkshire in the last few seasons, in some cases causing appreciable losses. The fungus is carried on the seed and, to obtain some idea of its frequency, 25 varieties were tested in 1956. Germination and percentage of infection after 10 days incubation was determined. No variety proved entirely free, the percentage infection ranging from 20 to 85 per cent, with a mean of 52 per cent.

Two varieties, Polar Bear and Grenadier, were selected for seed treatment trials. Both lots of seed had a germination of over 70 per cent. The treatments applied were: steeping in 1 in 1,200 mercuric chloride solution for 25 minutes followed by washing in cold running water for 30 minutes; hot-water treatment for 25 minutes at 110, 120, 122, 125, and 130° F respectively; dusting with thiram dust (50 per cent TMTD); and dusting with ceresan. 50 seeds were used for each treatment, 10 to a petri dish. The means of the five tests are given in the Table below. For the dusting treatments enough dust was applied to give a good covering to each seed, the excess dust being sieved off.

Mean Percentage Infection and Germination

Treatment	Polar Bear		Grenadier	
	Infection	*Germination*	*Infection*	*Germination*
Untreated	80	76	66	82
Mercuric Chloride	22	76	6	80
Hot-water 25 min at:				
110° F	68	80	80	82
120° F	46	56	46	72
122° F	44	66	26	64
125° F	38	62	34	56
130° F	10	24	14	50
Thiram dust	0	76	0	80
Ceresan dust	0	76	0	74

The results show the marked superiority of the dry treatments over the wet. Hot-water treatment at a temperature that did not harm germination gave no reduction of infection. Baker and Davis (*Plant Dis. Reptr.*, 1950, **34**, 403–13) recommend hot-water treatment for 30 minutes at 125° F but they recorded that this lowered germination by 10 per cent in one-year-old seed, and by 26 per cent in two-year-old seed, while in three-year-old seed the germination was only 8 per cent against 38 per cent in the untreated. Our treatment at 125° F for 25 minutes reduced the germination by 14 per cent in the variety Polar Bear and by 26 per cent in Grenadier.

In fairly large-scale trials at the Stockbridge Experimental Horticulture Station, Cawood, Yorks, in 1955, good results were obtained with the mercuric chloride treatment (as in our laboratory tests), with 50 per cent thiram dust, and with hot-water treatment at 125° F for 20 minutes. In 1956 all the seed was treated with thiram dust with excellent results. In general thiram dust treatment appears to be the most convenient, and it has the advantage that the material is non-poisonous. We have used it on a number of occasions since and the results have all been satisfactory.

AN ESSEX FARM TRIAL ON THE INSECTICIDAL CONTROL OF POTATO VIRUS SPREAD

by L. BROADBENT AND G. D. HEATHCOTE
Rothamsted Experimental Station, Harpenden, Herts
AND
E. CHRISTINE MASON
National Agricultural Advisory Service, Cambridge

IN many parts of England potato stocks cannot be kept safely for longer than two years because of the danger of virus diseases. Indeed, many growers buy new certified seed every year to insure against losses from these diseases. Although successful, this policy is expensive, and a trial was started in 1952 on a farm in Essex, where the normal practice was to plant the whole acreage with new stock seed each year, to find out if new seed need be purchased so frequently.

Stock seed of the variety King Edward was used. Treatments were randomized, but not replicated, and each plot of about 1¼ acres consisted of a strip 51 rows wide running the length of the field. At the end of the season the tubers from the central 30 rows of each plot (less 20 yd headlands) were clamped separately, and the seed-sized ones, unchitted, were used to plant a similar area on another field, for the same treatment, the following year.

Four insecticides were used in 1952: two contact, parathion and toxaphene, were sprayed fortnightly six times; two systemic, dimefox and demeton, were applied three times at monthly intervals, either as sprays or dribbled on to the soil half-way up the ridge. It was hoped that these treatments, if they were applied as soon as the plants emerged and were continued until mid-August, would give continuous protection against aphids during the season. Treatments were applied with a "Cambridge" high-volume trailer-type spraying machine. The boom carried one nozzle above each row, and one on either side on underleaf lances. For soil application the top nozzles were closed and the lower ones were used with the swirl plates removed. The rates of application are given in Table 1, and the insecticides were applied in 100 gallons of water per acre. In 1952 one unsprayed area was left as a control plot, but in subsequent years there were three.

A sticky aphid trap was operated among the unsprayed potatoes, and counts of aphids on the foliage of the central 30 rows of each plot were made fortnightly, about five days after spraying (Table 1). Aphid control was poor on the

toxaphene and dimefox (sprayed) plots in 1952, so these treatments were omitted in subsequent years. Aphid control on the other treated plots was good every year.

The period from late May until mid-July 1952 was warm and sunny, with little rain, but from then until early September the weather was variable, with considerable rain during early August. Aphids were relatively few: *Aphis nasturtii* (Kltb.) was the most numerous species, 467 per 100 leaves being counted on July 2, compared with 122 *Myzus persicae* (Sulz.) and 19 others. Only 10 *M. persicae* were trapped during the season. The haulms were destroyed with acid in late September.

June and July 1953, were dull, but the first half of August was warm and sunny. Aphids were more numerous than in 1952 and most occurred during the last week of July. *M. persicae* was predominant (996 per 100 leaves and 106 others on August 4), and 186 were trapped throughout July and early August. The haulms died naturally in mid-September.

In 1954, June and July were cool and dull, with frequent rain. The first half of August was fine, but the rest of the growing period was cool and wet. The weather made spraying to schedule impossible: five sprays were applied, the last two at three-weekly intervals. Aphids are often few in this type of weather, but in 1954 they were very numerous. 1618 *A. nasturtii*, 1034 *M. persicae*, 497 *Macrosiphum solanifolii* Ash. and 305 others were counted on 100 leaves on August 3, but the trap showed that the activity of *M. persicae*, the principal virus vector, was mostly restricted to the period of the summer dispersal, 54 being trapped during the last week of July and the first of August. The haulms were destroyed in late September.

TABLE 1

Treatments and Total Aphids Recorded in 5 or 6 Counts per Plot, each made on 100 Leaves (Upper, Middle and Lower Leaves on 33 Plants)*

Treatment	Active ingredient per acre per application *lb*	No. of Aphids		
		1952	*1953*	*1954*
Dimefox spray	2	192	—	—
Dimefox soil dribble	4	61	52	22*
Demeton (Systox) spray	1	23	7	16*
Demeton (Systox) soil dribble	2	11	37	17*
Parathion spray	1·25	9	21	32*
Toxaphene spray	2	395	—	—
Unsprayed (average of 3 plots in 1953 and 1954)	—	815*	1,549	3,774*

In 1952, 10,000 plants were examined, but only one was seen with leaf roll, and none with rugose mosaic (virus Y). Virus was introduced by visiting aphids during the first year, showing as one per cent of plants with leaf roll, and 2·5 per cent with rugose mosaic in 1953 (Fig. 1). Leaf roll virus was not brought in from a distance during 1953 or 1954 because the incidence of leaf roll did not increase in the treated plots during the following years; it increased in the unsprayed plots as a result of aphid activity within the crop, showing in 5 per cent of the plants in 1954 and in 26 per cent in 1955.

The virus Y introduced during the first year spread to about 5 per cent of the plants during the second, in both the treated and unsprayed plots, so that it was not possible to find out if the virus was again brought from a distance in subsequent years. Virus Y spread less rapidly in the plot sprayed with the contact

insecticide parathion than on those treated with systemic insecticides, but as the trial was not randomized, this result may be a chance effect. It must be remembered also that the systemic insecticides were applied three times, but parathion six times. The difference in mosaic incidence between the plot sprayed with demeton and those in which demeton or dimefox were dribbled on the soil might have been due to greater initial incidence in 1953 (Fig. 1), because the ratios of mosaic incidences in the two types of treatment in 1953 and 1955 were the same.

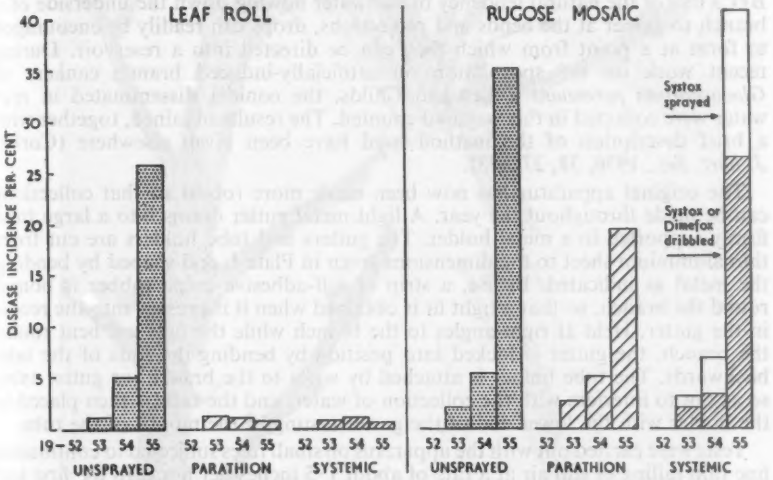


Fig. 1. Incidence of leaf roll and rugose mosaic (virus 7) in the spraying trials on King Edward potatoes, 1952–55.

The results confirm those of Broadbent, Burt and Heathcote (*Ann. appl. Biol.*, 1956, **44**, 256–73) at Rothamsted. Both contact and systemic insecticides prevented the spread of leaf roll virus from infected plants within the crop, but had less effect on the spread of virus Y, which spread more on sprayed plots than at Rothamsted. Insecticides did not prevent the introduction of either virus by winged aphids flying from other potato crops during the summer. Nevertheless, a good crop was obtained for three successive years, showing that it was not necessary to renew the seed stock every year.

The dispersal of infective aphids from crops containing a proportion of infected plants could be prevented by spraying them once or twice during early July. Although seed tubers might not be kept from such infected crops, preventing the summer aphid flights over a wide area would enable farmers to save seed for many years from healthier stocks which had been sprayed early and rogued to limit virus spread within the crop.

We are indebted to Messrs. Tinney & Hitchcock for providing the land and the seed tubers, and to their Farm Manager, Mr. Moss, for changing the trap covers. Thanks are also due to Messrs. Fisons Pest Control for providing and applying the insecticides.

A TRAP FOR WATER-BORNE SPORES

by A. T. K. CORKE

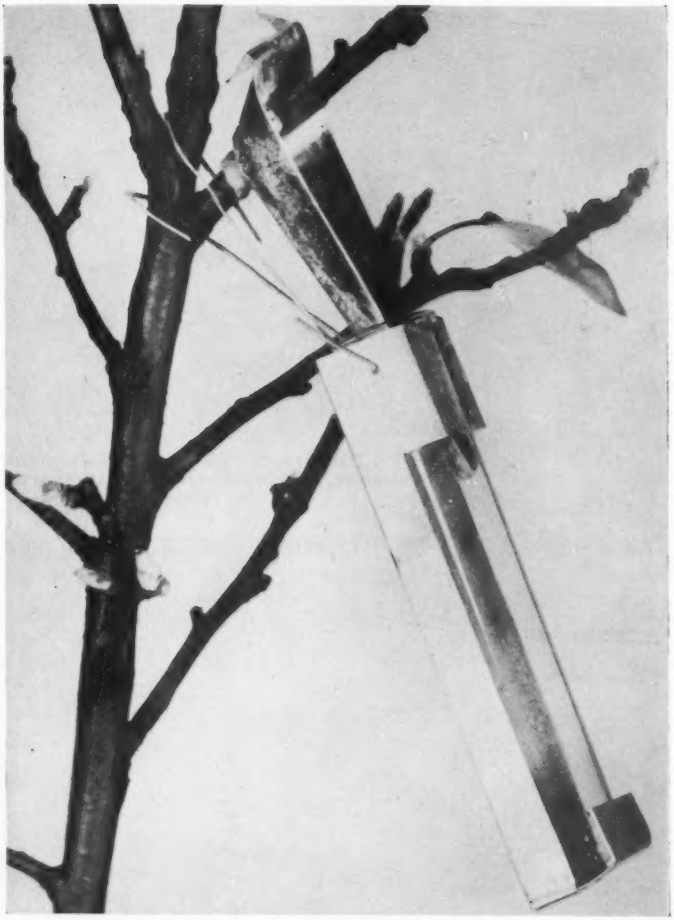
Long Ashton Research Station, Bristol

BECAUSE of the natural tendency of rainwater flowing down the underside of a branch to gather at the bends and projections, drops can readily be encouraged to form at a point from which they can be directed into a reservoir. During recent work on the sporulation on artificially-induced branch cankers of *Gloeosporium perennans* Zeller and Childs, the conidia disseminated in rain water were collected in this way and counted. The results obtained, together with a brief description of the method used have been given elsewhere (Corke, *J. hort. Sci.*, 1956, **31**, 272–83).

The original apparatus has now been made more robust so that collections can be made throughout the year. A light metal gutter drains into a large tube firmly supported in a metal holder. The gutters and tube holders are cut from thin aluminium sheet to the dimensions given in Plate I, and shaped by bending the metal as indicated. In use, a strip of self-adhesive crêpe rubber is bound round the branch, so that a tight fit is obtained when it is pressed into the recess in the gutter. Held at right-angles to the branch while the tabs are bent round the branch, the gutter is locked into position by bending the ends of the tabs backwards. The tube holder is attached by wires to the branch, or gutter tabs, so as not to interfere with the collection of water, and the tube is then placed in the holder with the lower end of the gutter resting in the mouth of the tube.

Tests were carried out with the apparatus on small trees subjected to continuous fine rain falling in still air at a rate of about 1·5 inches per hour. In the first test the trap was attached to the main stem below the lateral branches, while a second trap was sealed to the stem below. Shields were placed below the upper trap so that only water which failed to enter the upper trap could enter the lower one. The water in each trap was measured as soon as either had filled, and each test was repeated ten times. Further tests were made with the trap on a lateral branch at an angle of 45° to the main stem. The results showed that an unsealed trap on the main stem could collect over 99·5 per cent of the water when the diameter of the stem was the same as that of the gutter recess ($\frac{1}{2}$ inch). The trap was equally efficient when held in position against a lateral branch of $\frac{1}{4}$ inch diameter, provided the branch below the trap was dry. When wet, over 3 per cent failed to enter the upper trap, and this loss was increased to nearly 18 per cent if the gutter tabs were not bent back sufficiently. Where a strip of self-adhesive crêpe rubber was used to provide a seating for the gutter at least 99·8 per cent of the water was collected in every test.

This apparatus for collecting rain water from branches has thus been shown to perform satisfactorily under exacting experimental conditions in still air, and it remains in position in the orchard so that collections can be made throughout the year. With an efficient method of collecting water it seems likely that counts of the number of water-borne spores present during any given period will reflect fairly accurately measurable variations in the number being disseminated. The siting of traps to collect spores from naturally occurring cankers may present problems which need not arise with artifically induced cankers. Branches selected for inoculation can be at a suitable angle and strong enough to support a trap at a later date, or in such a position in the tree that additional support is readily available. When collection is to begin, snags likely to deflect water drops should be removed and the trap placed about two inches below the canker.



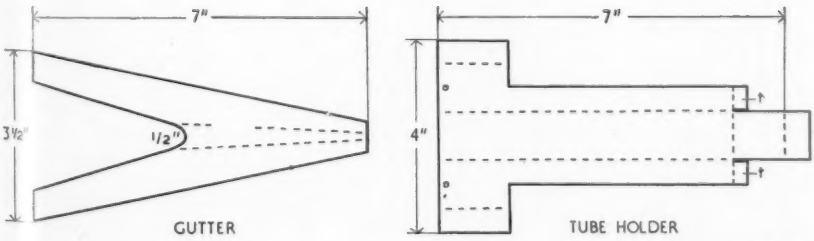
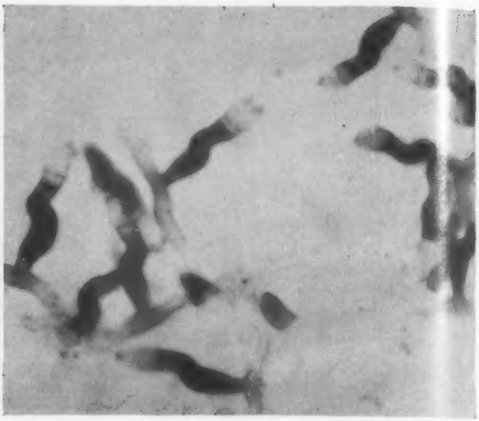


Photo: *Long Ashton Research Station*

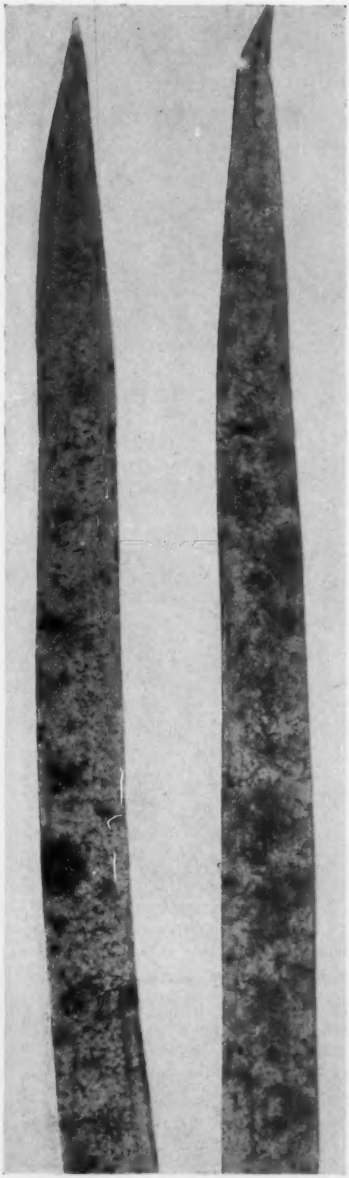
The trap assembled for use, and *below*, patterns for the metal parts. The gutter is bent through 60° along the dotted lines, and the tube holder through 90°. The strengthening tabs " t " are bent up last.

PLATE I

GREASY BLOTCH OF CARNATION (*see p.* 76)



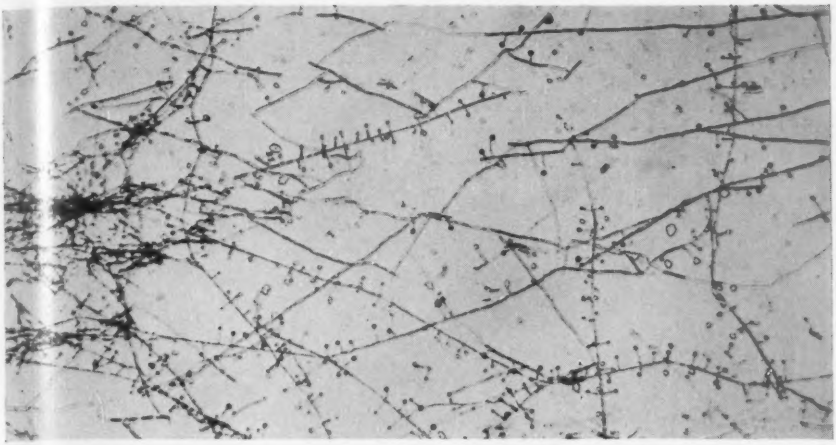
1. Dark twisted conidiophores of *Zygophiala jamaicensis* on surface of leaf. The top of the conidiophore is hyaline; no spores are shown.



2. Symptoms on leaf.

3. Fibrillate pattern on infected area of leaf.

PLATE II



1. *Cephalosporium aphidicola* on Sabouraud's agar.

2. *Left:* Adult whitefly with large ventral wax bundles. *Right:* Adult whitefly covered with hyphae of *Cephalosporium aphidicola.*

PLATE III

AUTOGENOUS NECROSIS IN THE TOMATO

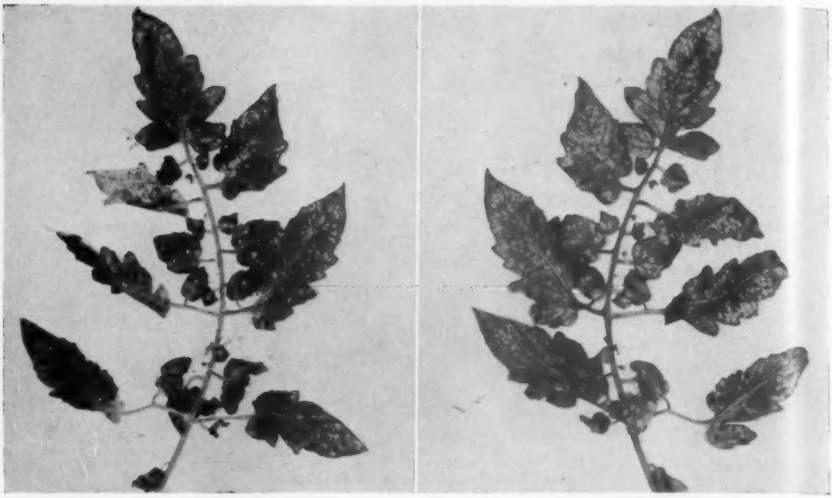
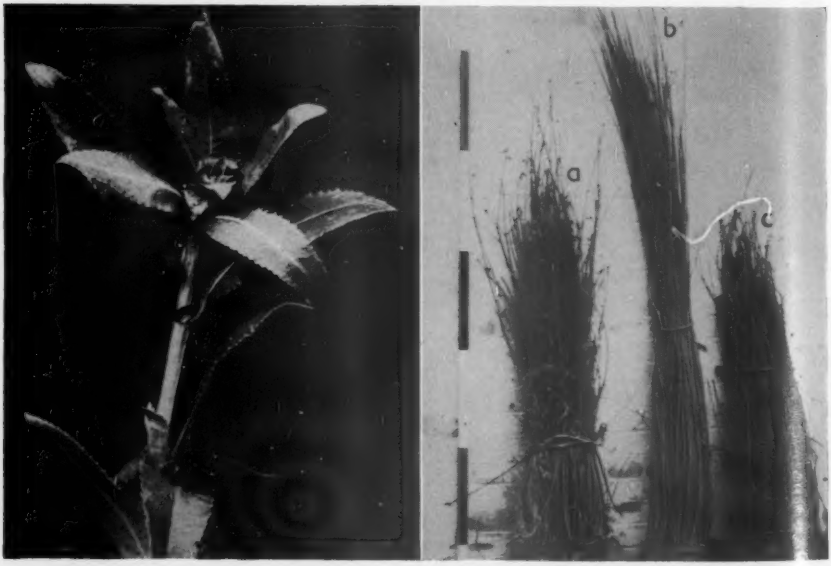


Photo: *John Innes Horticultural Institution*

1. Symptoms on leaf of tomato variety Syston Cross. *Left:* Upper surface. *Right:* Lower surface.

BUTTON TOP MIDGE IN WILLOWS (*see p.* 50)



2. *Left:* Button top midge gall in June. *Right:* Unsorted sheaves (*a*) DDT treated May 25 to mid-June 1956, (*b*) DDT treated May 4 to mid-June 1956, (*c*) untreated 1955.

PLATE IV

AUTOGENOUS NECROSIS IN THE TOMATO

by P. R. DAY

John Innes Horticultural Institution, Bayfordbury, Herts.

IN June, 1957, I received from the National Agricultural Advisory Service reports of a disorder of the tomato variety Syston Cross. This F_1 hybrid variety was introduced by Messrs. Harrisons of Leicester and was claimed to be immune to *Cladosporium fulvum* Cooke. The symptoms of the disorder first appear as small brown necrotic spots visible on the lower surface of the leaves. These spots enlarge, the centres becoming brown, and coalesce (Plate IV, 1). Many plants show a severe chlorosis in addition to necrosis. In severe cases the leaf area, if entirely necrosed and shrivelled, presents a scorched appearance. Rarely the peduncles and pedicels show necrosis starting as small flecks. In four cases reported, from 2 to 13 per cent of the plants showed symptoms.

A disorder of tomatoes which appears to be similar to that described was first reported by Alexander (1938) working with families derived from crossing the red currant tomato *Lycopersicon pimpinellifolium* with the *L. esculentum* variety Globe. Langford (1948) published a detailed account of the disorder and called it autogenous necrosis. His account of the symptoms is as follows:

> ". . . the first clearly recognisable symptom of the abnormality is the occurrence of small, angular, yellowish to brown necrotic spots near the tip of one or more of the lower leaves. Such spots are much more apparent on the lower than on the upper surface of the leaf. Accompanying the spotting is a downward and inward cupping of the leaf. Later the necrotic spots become larger and more numerous, with coalescence, and plainly visible from the upper surface of the leaf as well as the lower one. . . . At any time the youngest growth remains normal. A plant in which severe necrosis has developed bears fruit of greatly reduced size. Under conditions of prolonged intense sunlight the affected plants may be completely browned except near the growing point, their leaves largely shrivelled and dead . . . . In the case of moderate and severe necrosis . . . and sometimes in cases of slight necrosis, characteristic pedicel symptoms develop, especially if the truss has been well exposed to the light . . . sometimes there are a few bits of green tissue but often the necrosis is so extensive that the whole truss presents a brown, killed appearance."

The symptom pattern in Syston Cross is very similar to this. Maximal expression of the symptoms is dependent on prolonged intense sunlight. My own experiments at Bayfordbury in 1952 and 1953 showed that in the dull summer of 1953 few symptoms developed in experimental necrotic lines planted in the field. Failure of symptom expression would mean that the necrotic types could not be rogued during the selection and appraisal of a new tomato variety.

Langford showed that autogenous necrosis results when a dominant gene (Cf_2) for immunity to *C. fulvum*, derived from *L. pimpinellifolium*, is associated with a recessive gene (**ne**) in the homozygous condition. The gene **ne** is derived from *L. esculentum*. L. *pimpinellifolium* has a dominant allele Ne at this locus and when this is present with Cf_2 necrosis does not occur. Thus *L. esculentum* variety Vetomold, has the genotype Cf_2Cf_2, NeNe. It is non-necrotic and breeds true.

The precise parentage of Syston Cross is a trade secret. I have learnt from the raiser (Mr. J. Bruinsma, Naaldwijk, Holland) that the *C. fulvum* resistant parent

was derived from a breeding line F–58 released by the Horticultural Experiment Station, Vineland, Ontario. F–58 is not a pure line and contains genes for resistance from the tomato varieties Vetomold (Cf_2) and V–121 (Cf_3) and the species *L. hirsutum* (E. A. Kerr, personal communication). It is, therefore, possible that Syston Cross contains one, two or all three of these genes.

Plants raised from seed of Syston Cross supplied by Messrs Harrisons were inoculated with *C. fulvum* in a test made at Bayfordbury. The variety was not uniformly resistant but plants were present which were resistant to races which would normally attack genotypes Cf_1, Cf_2, Cf_3, and Cf_2Cf_3. The resistance of these plants is most likely to be due to the presence of the gene derived from *L. hirsutum*. In two of the four cases of necrosis on Syston Cross *C. fulvum* infection was also present in the crop. No plant infected with *C. fulvum* showed necrotic symptoms. I was able to confirm this in one case myself.

The lack of uniformity of resistance to *C. fulvum* in Syston Cross is most likely due to the fact that the resistant parent was not a pure line. In producing the F_1 hybrid seed stock the seed from different resistant mother plants was bulked by the raiser. The ratios of necrotic to normal plants found in commercial plantings of the variety are therefore meaningless.

There can be little doubt that the cause of necrosis in Syston Cross is genetic and is associated with the presence of a gene for resistance to *C. fulvum*. Without further evidence it is not possible to say if the gene involved is Cf_2 or the gene from *L. hirsutum*.

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FIELD INFESTATION OF ALTERNATIVE HOST PLANTS BY WHEAT BULB FLY

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THOUGH wheat is considered to be the chief host plant, there are numerous records of the wheat bulb fly breeding in, or infesting, other plants. Gemmill (1927) recorded that barley, rye, couch grass and possibly cocksfoot served as host plants. Gough (1946) recorded that, on arable land, larvae were found in *Poa trivialis*, *P. annua* and *Agrostis alba v. repens* as well as couch grass and that *Phleum pratense* and *Lolium perenne* were infested in the laboratory. Laboratory experiments (Stokes, 1955) have extended the known host plant range of wheat bulb fly. There are, however, no quantitative data referring to natural infestations of alternative host plants. Observations were made in the spring of 1957 on a permanently fallow plot about 60 yards × 13 yards situated in the centre of Bones Close Field at Rothamsted. This fallow is maintained to provide a source of low fertility soil for pot experiments. It receives no fertilizer and is normally kept free of weeds by cultivation. The surrounding 16 acre grass field, part of which was reclaimed from woodland in 1942, has been down to a cocksfoot, meadow fescue, timothy, and white clover mixture since 1951. In January 1957, eighty soil

samples each 2½ inches diameter and 8 inches deep were taken from the fallow plot and examined for wheat bulb fly eggs using a standard flotation method. They showed that the plot had an infestation of about 500,000 wheat bulb fly eggs per acre, i.e., about eleven per square foot. No eggs were found in forty similar soil samples taken from the surrounding grass field.

During the mild winter there was a considerable germination of grasses and weeds on the fallow. Cultivation of the plot was suspended to allow the plants uninterrupted development. On February 12, wheat grains were sown in six quadrats each one foot square, and on February 18 six more quadrats were planted with wheat seedlings which had been previously germinated in the laboratory.

On March 13 a sample of weeds and grasses taken from the plot was examined for wheat bulb fly larvae. The main series of plant samples was collected and examined on April 1 and 2. These samples consisted of all the plants from the twelve one-foot square quadrats in which wheat had been sown or planted and the plants from six other one-foot square quadrats. The shoots of all the plants from these eighteen samples were dissected and examined for wheat bulb fly larvae or symptoms of damage. As individual plants could not be distinguished the number of shoots was recorded. The plants found in the samples could be divided into three groups:

Known host plants: wheat and *Agropyron repens*—species which wheat bulb fly is known to infest and from which flies have been reared.

Suspected host plants: Dactylis glomerata, Lolium perenne and possibly *L. multiflorum, Poa annua,* and *Phleum pratense*—species in which larvae have previously been found or damage recorded though no flies have beeen reared.

Other plants: Stellaria media, Cirsium arvense, Veronica sp and *Plantago* sp. — species in which larvae have not been found or damage recorded.

The results are summarized in the Table on page 60. Four wheat bulb fly larvae were found, two in wheat plants, one in *D. glomerata* and one in *Lolium*. Although the infested wheat plants came from a quadrat in which wheat seeds had been planted their size and stage of development suggested that they were autumn sown volunteers. Five shoots of *P. annua*, three of wheat, two of *A. repens*, one of *D. glomerata* and one of *Lolium* also showed damage characteristic of wheat bulb fly although no larvae were found in them.

DISCUSSION

The occurrence of a considerable infestation of wheat bulb fly eggs in the fallow plot, to the exclusion of the surrounding grassland, is in itself a point of interest and provides a striking example of the attraction of even a relatively small area of fallow to the ovipositing females. Moreover the fallow plot was relatively isolated. The nearest potential source of flies responsible for the infestation was part of the adjoining field, 100 yards away, which carried winter wheat in 1956 after potatoes in 1955. It is not known if this wheat was infested. The nearest known source of wheat bulb flies was Broadbalk, 400 yards away.

The results of the plant counts support previous field observations and laboratory experiments on host plant range. Quantitatively, the striking feature of the results is the low survival rate. The eighteen square foot quadrats could be expected to contain about 200 eggs (eleven per square foot) but only three larvae were recovered from the plants in them, a survival of only 1·5 per cent. The shoot density of known and suspected host plants was about 100 per square foot. This is comparable with the shoot density of an average crop of wheat, where a much higher survival rate would be expected and has been observed on other occasions (Gough, 1947). The wheat plants in the quadrats were probably sown or planted too late to become infested, but the data for the other species suggest that they are much less readily attacked than winter wheat.

Numbers of Shoots, Infested Shoots (in Brackets) and Damaged Shoots (Raised Figures) from one Preliminary Sample and 18 Square Foot Quadrats.

	Known host plants		Suspected host plants				Other plants*			
	Wheat	*Agropyron repens*	*Dactylis glomerata*	*Lolium perenne*	*Poa annua*	*Phleum pratense*	*S.m.*	*C.a.*	*V.sp.*	*P.sp.*
March 13			152	68[1](1)	43				5	
April 1–2										
1	4		4		91[1]		15		1	
2	15(2)				41				5	
3	11		5		14					
4	14		4		36[2]					
5	7				13					
6	3		30(1)	15	275[1]					
7	15[1]		25	10	10			1		
8	6	74[2]	8	19					1	
9	16									
10	15		19	6		10	27		5	
11	10	4	10	12			8	1		
12	14[2]		74		8		29	1	1	
13			10	33	119					
14		24		50						
15			21	18	47[1]		1			
16			25[1]	6						
17			5	91						
18					324					2
Totals	130	102	240	260	978	10	80	3	13	2

* *S.m.* = *Stellaria media*. *C.a.* = *Cirsium arvense*. *V.sp.* = *Veronica sp.* *P.sp.* = *Plantago sp.*

There is some experimental evidence to suggest that this is so for other graminaceous species. In a series of pot experiments carried out by one of us (B. M. S.) in 1955 and 1956, newly emerged wheat bulb fly larvae were placed in the centre of pots in which wheat and another plant species were grown in approximately equal amounts. By comparing the numbers of larvae subsequently found in the test species with those found in the wheat plants a measure of their susceptibility to attack relative to wheat was obtained. The results expressed as percentages (wheat = 100) were as follows:

Agropyron repens	Barley	*Agrostis tenuis*	Rye	*Festuca pratensis*	*Poa pratensis*
133	83	57	26	23	18

Clearly, further field investigation and experimental work on this aspect of the wheat bulb flies host plant relationship is required.

Dr. K. Mellanby drew our attention to the infestation of the fallow and suggested that we made observations there. Mr. J. W. Stephenson and Mr. J. R. Lofty helped to collect and examine the soil samples.

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CLUB ROOT SURVEY IN WALES, 1956

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CLUB root appeared to be prevalent in brassica crops in Wales in the late summer of 1956, despite dry conditions prevailing earlier in the season, but information available was patchy, and a clear picture of its distribution and economic importance was not readily seen. With seasonal conditions apparently favouring the disease, a survey was considered most opportune. Such a survey had not previously been made for the whole of Wales, although an extensive survey of the four northern counties was made nearly thirty-five years previously by Whitehead (*Welsh J. Agric.*, 1925, **1**, 176–84).

The 1956 survey was based on the examination by each N.A.A.S. district advisory officer of approximately ten crops of swedes, turnips, rape, kale or cabbage, selected at random and distributed throughout his district. For each crop examined, assessment of the disease was coupled with the taking of a soil sample for chemical analysis. Sixteen borings for each soil sample were taken throughout the crop, and at each point plants were examined for disease. Freedom from disease or the level of infection in the sample was recorded. Information also recorded included variety, extent and distribution of damage, previous cropping, manurial treatment including previous liming, soil type and topography.

The three categories into which plants were classified at each of the sixteen sampling points within a crop were: "free from visible infection", "mostly small galls on roots only" or "large galls predominating". By assigning to these categories arbitrary scores of 0, 1 and 5 respectively, it was possible to have a total score for a crop ranging from nil to a maximum of 80 where large galls predominated in all sixteen samples. In practice, field observations of anticipated substantial reductions in yield were associated with scores of 20 and over. In summarizing the data for analysis, therefore, crops with a score of under 20 were considered to have "slight to moderate" infection, whereas scores exceeding 20 denoted "severe" infection.

Possible confusion was anticipated in the swede samples arising from the occurrence of hybridization nodules, and several samples for laboratory checking were received at Aberystwyth, Cardiff and Bangor. As a source of error, however, the low score assigned to small galls that might be confused with hybridization nodules was overshadowed by that given for large galls when considering the degree of infection that would be expected to produce a visible reduction in cropping. Where only a few of the sixteen samples were recorded as having small galls, these were assumed to be due to club root. Out of 156 swede crops examined, small galls exclusively occurred only in 36, and the maximum score in any of these crops was 9.

DISTRIBUTION AND INTENSITY OF THE DISEASE

Records were received in respect of 433 crops in 13 counties and these showed a substantial proportion of the brassica crops in Caernarvon, Radnor, Brecon, Glamorgan and Monmouth, to be affected with club root, some very severely. Fewer crops were affected in Cardiganshire, and in Anglesey, Carmarthen, Denbigh and Merioneth, only a few were affected, and in these the infection

was mostly slight. Records from Flint, Pembroke and Montgomery were insufficient for a reliable impression to be formed.

Table 1 shows the intensity and distribution of club root in Wales as assessed on crops of swedes, turnips, rape, cabbage or kale selected at random in each county. The table also shows, for each county, the percentage of the respective crops comprising the samples on which the assessments were made.

From the individual records it was clear that, of the crops examined, swedes are most frequently and severely affected and kale least. This is evidenced in the summarized results by the higher proportion of diseased crops in those counties where swedes predominate, and the lower incidence of recorded club root where kale is the more widely-grown crop. An extreme example of this was found in a comparison between the records from Caernarvon and those from Merioneth or Monmouth. No correlation was evident between the incidence of club root and the taking of a susceptible crop during the previous four years. This was so even if grass were considered to be a possible source of infection, because of the likelihood of roots having been fed to stock overwintered on it.

TABLE 1

Intensity and Distribution of Club Root in Wales, 1956, in Relation to the Percentage of Swede and other Brassica Crops in the Total Number of Crops Surveyed in Each County

County	Percentage of Total No. of Crops					Total No. of Crops	Percentage of Total No. of Crops with Club Root		
	Swede	*Turnip*	*Rape*	*Cabbage*	*Kale*		*Severe*	*Slight*	*Absent*
Caernarvon ..	66	16	0	0	18	50	18	44	38
Radnor ..	46	23	8	3	20	35	14	37	49
Brecon ..	52	22	13	0	13	31	16	26	58
Glamorgan ..	37	2	16	4	41	54	9	32	59
Monmouth ..	31	7	4	13	45	75	13	16	71
Cardigan ..	20	3	45	7	25	40	15	10	75
Anglesey ..	56	8	0	0	36	36	8	6	86
Carmarthen ..	9	0	41	5	45	22	9	5	86
Denbigh ..	23	8	15	0	54	39	3	5	92
Merioneth ..	23	6	18	6	47	34	0	6	94
Montgomery	25	38	0	0	37	8	0	25	75
Pembroke ..	0	0	20	0	80	5	20	20	60
Flint	0	0	25	0	75	4	0	25	75
Wales ..	36	10	14	4	36	433	11	20	69

In his review, in 1925, based on more than 400 visits to farms in the four northern counties of Wales, Whitehead recorded that the most extensive losses from club root occurred in Caernarvon, with only the western end of the Lleyn peninsula, and a small area between the railway and Great Orme, relatively free from infection. Holyhead Island and forty square miles of Anglesey between the Menai Straits and the eastern edge of Malldraeth Marsh were also severely affected. Serious or heavy attacks were recorded as having occurred at Penyffordd, Rhosemor, Halkyn and in the St. Asaph district of Flint, and in the upland areas of Denbighshire. The Vale of Clwyd, however, seemed to be fairly free except for slight attacks around Ruthin and Denbigh. The prevalence of club root on the lighter soils of Flint was attributed to a high proportion of swedes in the root crop.

SOIL FACTORS AND CLUB ROOT

To avoid the complication of differing host susceptibility, attempts in the present survey to correlate severity of attack with soil factors were confined to swedes, in respect of which the greater number of records was received. Information available on soil texture, drainage and topography was not sufficiently complete to permit analysis, and no ready correlation was apparent with any of the data obtained from soil analyses other than, possibly, with available calcium.

TABLE 2

Incidence of Club Root Infection in Swede Crops at Different Levels of Available Calcium

	Available Calcium (mg per 100 g) (Including free $CaCo_3$ where present)							
	under 100	101 to 200	201 to 300	301 to 400	401 to 500	501 to 600	601 to 700	over 700
Range of pH all crops	5·1 to 5·5	4·8 to 5·9	5·0 to 6·8	5·4 to 7·6	5·4 to 7·4	6·0 to 7·8	6·7 to 7·8	6·0 to 8·2
Total number of crops	2	16	25	40	17	21	6	6
Percentage infected ..	50	50	68	47	30	38	33	50
Severely infected ..	50	31	24	22	12	5	0	0

Table 2 shows the number of affected and unaffected crops at different levels of available calcium as determined from their soil samples. The range of pH for each group of records is also given. Although no clear correlation was apparent between individual attacks and soil pH, the highest proportion of crops affected with club root was found at levels of available calcium below 400 mg per 100 g. Above this level, only eighteen out of fifty crops were affected, and only three severely. The fall-off in percentage of crops with severe infection at the higher levels of available calcium is shown very clearly in the table. These observations are consistent with those made by Whitehead (*Welsh J. Agric.*, 1936, **12**, 183–92) in the course of liming trials in North Wales.

Thanks are due to members of the N.A.A.S. county advisory staffs who made the field inspections; to the advisory chemists at Aberystwyth, Cardiff and Bangor for the soil analyses; to Dr. J. Bradley Jones and Mr. D. C. Gwynne; and to Mr. Howard Morgan, Chairman of the Technical Organization Sub-committee for Wales, for his sponsorship of the survey.

FIELD TRIALS ON THE ASSESSMENT OF WHEAT BLOSSOM MIDGE, 1954-56

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DURING the years 1954–56 field trials were carried out on the wheat blossom midges *Contarinia tritici* Kirby and *Sitodiplosis mosellana* Gehin to obtain information on wheat yields in relation to larval abundance in commercial crops, and to investigate problems in assessing the larval infestation. In 1956 the trial was enlarged to include an assessment of cereal thrips. The basic plan was to protect the crop continuously from attack on one series of plots and to allow the midge population to build up on the other.

The experiments were initiated as a result of reports of serious and widespread blossom midge attacks in Ireland in 1951–52. In Britain the only attempts to estimate damage and yield losses have been made by Barnes on the wheat crop on Broadbalk Field, Rothamsted. He has already described very fully the biology of the midges and the methods he has developed for assessing larval infestation (Barnes, 1956).

Adult midges emerge from the soil in June and July. They live only for about 36 hours, and appear to be most active when the sun is low or obscured and there is little or no wind or rain. Females of *C. tritici* can oviposit successfully only in the emerging ears: *S. mosellana* emerges later and oviposits in older ears than does *C. tritici*. The eggs of both species hatch in a few days and the larvae mature in about three weeks. *C. tritici* larvae feed on, and destroy, the unfertilized florets, and there is a very wide range in the numbers of larvae per floret, commonly 5–30. *S. mosellana* feeds on the young grain, more or less inhibiting its growth, and there are usually only one or two larvae per floret. On maturity the larvae of both species leave the ears and form cocoons in the soil. Once the larvae are mature the time they leave the florets depends on weather conditions: a hot dry period tends to stop movement, and the onset of moist weather to stimulate it. There is only one generation per year on wheat.

An accurate method of assessing larval infestation has been developed by Barnes (1953). The plots are visited to determine the beginning of ear emergence, and the peak period of midge activity is assessed from daily evening collections of ovipositing females together with the daily emergence of midges in an open unheated insectary. A series of "pre-samples" of ears is then taken at frequent intervals to trace the development of the larvae to maturity and the beginning of migration. Normally there is a period of at least several days during which the larvae are nearing maturity, but few have migrated—this is the only period during which larval numbers can be accurately estimated. At the judged "peak" a large sample of ears is assessed; a misjudgment of the peak can be corrected from the "pre-samples".

Our aim has been to try simplified versions of Barnes's methods of prediction and assessment, the ultimate purpose being the assessment of losses, due to wheat blossom midges, on sites throughout the country. Unfortunately infestations on the experimental sites were very low in all three years and had no effect on yield. However, some information was obtained on the correlation of midge activity and ear burst, and on the use that might be made of these processes to predict the best date to assess the larval infestation.

The work was done on commercial crops of wheat at the Hertfordshire Institute of Agriculture, St. Albans, on typical clay-with-flints soil. The 1954 site was a 4 acre crop of Progress spring wheat following sugar beet, winter wheat (two years) and a long grass ley. The 16 plots, each 28 yards long by 12 rows wide, were in eight replications of two treatments, sprayed and unsprayed. In 1955 the site was an 18 acre crop of spring sown Atle following ley grass (three years) and dredge corn that included some wheat: the layout was unchanged. In 1956 the same field was used the crop being winter sown Cappelle Desprez ; the number of replications was reduced to six. In an attempt to estimate populations of cereal thrips and the damage they caused, if any, the number of treatments was increased to four to include spraying against: thrips only, midges only, both pests, and unsprayed.

SPRAYING

One series of plots was sprayed, in order to protect it for most of the period of ear burst, against wheat midge attack and the other series was left unsprayed. The insecticide chosen was DDT since it had already been used successfully in Ireland (Mullin, Fox and Brady, 1952). A proprietary DDT miscible liquid was used at a concentration of 0·1 per cent w/v DDT at two gallons per plot in 1954; in 1955–6 a more efficient knapsack sprayer was available and the dose was reduced to one gallon per plot, as this gave adequate cover.

The site was visited daily just before earing began, and the first spray was applied when the first ears were emerging. The number and timing of the rest of the applications was judged according to the rate at which earing was completed, so that a more or less continuous cover was maintained throughout this period. Thus in 1954 sprays were applied on June 19, 22, 28 and July 1; in 1955 on June 22, 25, 29 and July 4. In 1956 one series of plots was sprayed on June 5, 12, 18, 21, 23 and 26 against blossom midges, another on May 15, 18, 22 and 25 against thrips, whilst a third series received all these sprays to control both pests. In 1954 counts of adults on the ears and collections by sweeping showed that the DDT kept midge activity on the sprayed plots at a negligible level; the data on ear infestation in all years confirmed the effectiveness of the timing.

OBSERVATIONS ON ADULT MIDGE ACTIVITY IN RELATION TO EAR EMERGENCE

Frequent counts of midges on the ears on the unsprayed plots were made to find the peak period of emergence and flight, to show whether or not this period coincided with ear burst and the emergence of insectary midges. The plots were sampled in the evenings, always in the same order, between 18.45 hours and 20.10 hours G.M.T. The midges were removed from the ears with a moistened brush or a suction tube. In 1954 all midges were counted on a random sample of 50 ears on each of four sprayed and four unsprayed plots on ten evenings from June 23 to July 2. The totals collected were:

on 2,000 unsprayed ears	117 *C. tritici* and 10 *S. mosellana*
on 2,000 sprayed ears	11 *C. tritici* and 1 *S. mosellana*

In 1955, midges were collected from untreated plots only, and in 1956 from 50 ears on each of two unsprayed plots.

The individual catches for the unsprayed plots in all three years are given in Table 1. This shows that only in 1955 was there a clear indication of a peak period of adult activity; in the other years observations were probably not made for long enough; in 1956 a sticky trap method was also used. The apparatus consisted of sticky microscope slides held in wire frames and suspended over the wheat crop on wooden crosses. The trap has already been described (George, 1957). Field counts were considered together with data on insectary emergence

obtained by Dr. Barnes. The midges were derived entirely from Broadbalk and were bred in the open unheated insectary at Rothamsted Lodge.

TABLE 1

Emergence of Contarinia tritici *in the Insectary, and Daily Catches in the Field, in Relation to Ear Emergence*

Date	1954		1955			1956		
	Ins.*	Field†	Ins.	Field	Ears‡	Ins.	Field	Ears
June 21 ..	2	—	0	0	0	0	—	8
22 ..	2	3	7	0	0	0	0	—
23 ..	8	63	9	0	0	1	0	—
24 ..	11	3	10	4	1	3	0	5
25 ..	20	0	18	79	14	10	0	—
26 ..	17	1	60	94	—	44	0	—
27 ..	28	6	88	274	54	102	0	3
28 ..	40	6	79	12	62	244	—	—
29 ..	41	0	67	1	60	350	—	—
30 ..	24	22	39	41	39	535	—	—
July 1 ..	42	6	26	3	—	841	—	—
2 ..	43	7	14	8	18	687	—	—
3 ..	28	—	12	0	—	618	—	—
4 ..	17	—	12	13	4	484	—	—
5 ..	7	—	7	35	—	442	—	—
6 ..	13	—	2	17	1	160	—	—
7 ..	1	—	6	5	—	84	—	—
8 ..	8	—	1	1	—	45	—	—

* Ins. Insectary emergence of *C. tritici*.
† Field Daily catch of *C. tritici* on ears of unsprayed plots.
‡ Ears Mean percentage of ears emerging on sprayed and unsprayed plots.

The rate at which the wheat ears emerged was measured to see whether the date on which the most ears were emerging was correlated with the field and insectary emergence of *C. tritici*, and whether this date could be used to predict the presence of a mature population of larvae in the ears. Ears were recorded as "closed" when still wholly within the ensheathing leaf, as "emerging" when there were one or more spikelets with at least one side exposed, "free" when all spikelets were fully exposed, and "flowering" when the anthers of at least one floret were exposed. Counts were made at two- or three-day intervals after the first "emerging" ear was seen on the plot area. All stems were recorded on four separate yard lengths of row chosen at random on one unsprayed and one sprayed plot. The results are shown in Table 2. The coincidence of the highest recorded percentage of emerging ears with adult emergence and field collections is shown in Table 1. Ear burst was not studied in detail in 1954. It was estimated that approximately 50 per cent of the ears had emerged on June 21 and 80 per cent on June 24. In 1956 ear emergence was early: 88 per cent of the ears were emerging on June 18, and by June 23, 49 per cent were in flower. Most of the crop consequently escaped attack by the mass of the midges which did not emerge in the insectary until the end of the month.

It seemed that a study of selective oviposition by *C. tritici* might lead to further refinement of the ear sampling technique. In 1956 a study was made to see whether oviposition takes place only on that side of the ear which is exposed first at earing, and whether this side of the ear can subsequently be identified. A paint brush was drawn horizontally across the sheathing leaf and across the newly exposed part of the ear in two places. This was intended to show later whether there was a

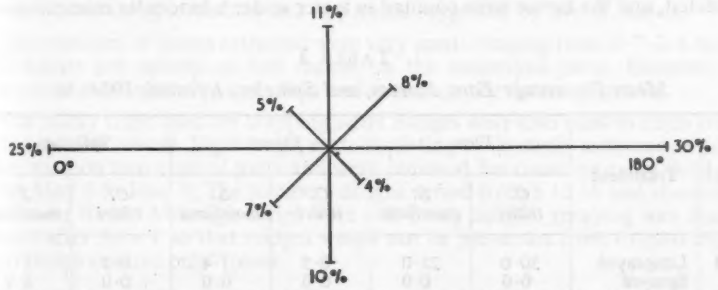
constant angle of rotation of the ear relative to the sheathing leaf, and any twisting within the ear. In June, 250 opening ears were marked. A month later, when the ears had flowered and were hardening, the paint marks were mapped. The figure below Table 2 shows the numbers of ears which had turned through various angles relative to the leaf since marking. Ears in the 0° position had either not twisted or had moved through 360°.

TABLE 2

Percentages of Ears Closed, Emerging, Free, and Flowering on Sprayed and Unsprayed plots, 1955 and 1956

1955	June 24		June 27		June 29		July 2		July 4		July 8	
	Uns.	*Spd*	*Uns.*	*Spd*	*Uns.*	*Spd*	*Uns.*	*Spd*	*Uns.*	*Spd*	*Uns.*	*Spd*
Closed	100	98	35	45	11	19	2	2	1	1	1	2
Emerging	—	2	58	50	61	58	15	22	7	9	1	1
Free	—	—	7	5	28	23	83	74	85	79	18	16
Flowering	—	—	—	—	—	—	—	2	7	11	80	81

1956	June 5		June 12		June 15		June 18		June 23		June 30	
Closed	93	99	22	40	23	35	5	11	18	19	—	2
Emerging	7	1	77	60	76	65	89	87	9	14	2	3
Free	—	—	1	—	1	—	6	2	42	36	2	3
Flowering	—	—	—	—	—	—	—	—	31	31	96	92



Twisting of ears relative to ensheathing leaf. One month after marking, 30 per cent of the ears were in their original position; the percentages which had turned into other positions were as shown.

About 45 per cent of the ears were distributed almost equally on either side of the 0°–180° line. These figures show that it would be very difficult to make an on-the-spot determination of the original outer side of an unmarked ear. The Swedish workers, Wallengren (1955) and Henning (1913) also studied differential oviposition by *C. tritici*. They found that oviposition takes place mainly on the outer or first-exposed side of the ear, which agrees with the few results obtained from this experiment: of 210 ears examined only five were infested; four of these were on the outer side of the ear only.

ASSESSMENT OF LARVAL INFESTATION

Ideally the infestation should be sampled when the larvae are mature, or nearly so, and before any have left the ears. In our trials the peak sample date was judged from dissections of check samples and confirmed from pre-samples taken

by Dr. Barnes on Broadbalk: there was no evidence that the dates had been wrongly chosen. Assuming these dates to be correct, and taking 21–24 days as an average period of larval development, it is possible to assess the value of the data obtained on ear burst, midge activity and insectary emergence as criteria for predicting the peak sampling date. This is indicated from the dates given below:

	1954	1955	1956
Peak sampling date	July 20	July 18	July 11
Peak insectary emergence	June 28–July 2	June 26–29	June 29–July 1
Maximum catch on ears	June 23	June 26	June 11
Maximum catch on traps	—	—	June 27
Highest percentage of emerging ears ..	June 21	June 27–29	June 18

In 1955, all three methods coincided closely, and a larval sample taken 21–24 days after the peak period assessed by any of the methods would have been correctly timed. In two years (1954 and 1955) a prediction based on peak insectary emergence or peak ear emergence would be accurate, but in 1956, when the ears emerged well before the peak of insectary emergence, ear burst proved the better criterion. The data from trapping and collecting in the field were too meagre to be useful except in 1955.

It appears that none of the criteria chosen gives a completely reliable prediction of when to sample for larvae; though one or other of two samples, based on ear burst and insectary emergence respectively, might be correct in most years. The work suggests that *C. tritici* and ear emergence may not coincide as frequently on commercial wheat crops as it has done on Broadbalk (Barnes, 1941).

The larval infestation (Table 3) was assessed from samples of complete ears taken at roughly equal intervals round the plots. To avoid a biased choice the stems were chosen near soil level. In 1954, from a plot sample of fifty ears, a sub-sample of five random ears was drawn for dissection; all the florets were dissected, and the larvae were counted in water under a binocular microscope.

TABLE 3

Mean Percentage Ears, Florets, and Spikelets Infested, 1954–56

Year	Treatment	Ears		Florets		Spikelets	
		C. tritici	*S. mosellana*	*C. tritici*	*S. mosellana*	*C. tritici*	*S. mosellana*
1954	Unsprayed	30·0	25·0	0·5	1·4	0·5	1·3
	Sprayed	0·0	0·0	0·0	0·0	0·0	0·0
1955	Unsprayed	27·8*	17·8*	0·8	0·8	0·8	0·8
	Sprayed	0·0*	0·0*	0·0	0·0	0·0	0·0
1956	Unsprayed	3·3	0·0	—	—	0·7	0·0
	Sprayed for:						
	Midge	0·0	0·0	—	—	0·0	0·0
	Thrips	3·0	0·0	—	—	0·6	0·0
	Both	0·0	0·0	—	—	0·0	0·0

* From 5-ear sample only.

In 1955, it was shown from an analysis of three years' data from Broadbalk (unpublished) that a considerable increase in accuracy could be expected if the ear sample was increased and the number of spikelets dissected per ear was decreased—both by a factor of four. Hence two sets of ear samples were taken, a five-ear sample dissected completely, and a twenty-ear sample in which only a quarter of the spikelets on each ear was dissected, the spikelets being chosen at roughly equal intervals and alternately on each side of the ear. The position of

infested florets on ears of both samples was recorded to obtain evidence of aggregation. There appeared to be a tendency for the lower spikelets to be least frequently infested, but it is not suggested that this may be generally true. In 1956 samples consisted of twenty ears per plot and two spikelets from the upper, middle and lower thirds of each ear were dissected.

A point that had to be considered was whether it is necessary, for correlation of infestation with grain yield, to know the number of larvae per floret as well as the number of florets or spikelets infested. If not, detailed dissection and counting could be discarded and there would be no need for accurate timing of the peak sample. There is evidence that in practice a *C. tritici* infested floret can be equated with a grain lost; the number of larvae per floret is immaterial. Barnes (1956) has concluded that a floret is made sterile by the presence of five or more *C. tritici* larvae. In this trial the number of *C. tritici* larvae per infested floret ranged from 1–28, but 83 to 97 per cent of these contained at least five larvae; furthermore the proportion of *C. tritici* infested florets observed to contain grain was very small. The degree of shrivelling caused by *S. mosellana* might vary appreciably with the number of larvae per floret, but in this case the numbers to be counted are relatively small.

ASSESSMENT OF THRIPS POPULATIONS

In 1956, the experimental area was enlarged and six replications of four treatments were laid down. The "thrips control" and "full control" plots were sprayed with DDT to prevent damage by thrips. Samples were taken during the critical time for thrips attack; that is, from the first migration in May, until ear burst. Each sample consisted of three random sub-samples of five shoots per plot. The thrips were forced out of the shoots by exposure to turpentine vapour for one hour using a method and apparatus suggested by Mr. T. Lewis.

The numbers of thrips extracted were very small, ranging from 0·7–2·5 larvae and adults per sample of five shoots on the unsprayed plots. However the extraction method showed promise and is to be more thoroughly tried.

The sticky traps used for trapping adult midges were also used to catch thrips flying over the wheat. Eight traps, each consisting of six sticky microscope slides, were used on two control plots and were removed for counting every third day from May 5 to June 1. The numbers caught varied from 6 to 56 and showed no particular trend. Although thrips were still being caught, spraying was discontinued after June 1 so that midges would not be prevented from ovipositing on the "thrips control only" plots.

TABLE 4

Grain Yields, 1954–56

Year	Treatment	Mean yield cwt per acre	
1954	Sprayed	46·8	±2·22
	Unsprayed	47·5	
1955	Sprayed	35·6	±0·37
	Unsprayed	37·8	
1956	Thrips control	33·8	±2·32
	Midge control	35·1	
	Thrips and Midge control	33·1	
	Unsprayed	37·5	

GRAIN YIELDS

In 1954, a rectangle of 84 square feet was cut by hand from the centre of each plot. The grain was threshed out on a Garvie machine and the moisture content of a number of sub-samples was determined by oven drying at the Wheat Commission Standard. The average for 20 samples was 12·9 per cent (range 12·8–13·3). The weights of grain are therefore presented uncorrected, at an assumed moisture content of 13 per cent oven dry weight. In 1955 and 1956 the plots were harvested by combine and yields were corrected to 13 per cent moisture content. The results are shown in Table 4.

CONCLUSIONS

Attacks by wheat blossom midge were very slight on the experimental sites in all years and caused no detectable loss in grain yield. In the virtual absence of any pest attack yields were in fact consistently lower on the sprayed plots, indicating that the DDT sprays had reduced grain yields.

Data were obtained on ear burst and adult midge activity in the field, and a study was made of their coincidence with midge emergence in an open insectary at Rothamsted, and of the relationship of all three processes with the peak population of larvae in the ears. There was strong evidence that ear burst and midge emergence were not simultaneous in two years (1954 and 1956). In 1955 all three processes coincided, as did insectary emergence and ear burst in 1954 and 1955. No one process could be used to predict when the peak population was present.

It is suggested that for damage assessment work pre-sampling might be dispensed with by taking two samples of ears, based respectively on the date of 50 per cent ear emergence and the peak period of insectary emergence, or of adult activity in the field; and by ignoring numbers of larvae per floret thus making the timing of the ear sample less critical. Reasons are given for suggesting that an adequate estimate of *C. tritici* infestation can be made without knowing the numbers of larvae per floret.

In 1956, the infestation of wheat by cereal thrips was measured during a period of about a month, ending at ear burst. The thrips were extracted from the shoots by a technique using turpentine vapour. The populations were extremely low and caused no detectable damage.

Thanks are due to the Director, farm manager and other staff of the Hertfordshire Institute of Agriculture for facilities and help; to Dr. H. F. Barnes for his guidance, and permission for use to be made of much unpublished data; to Mr. H. D. Paterson for a statistical analysis, and to Mr. T. Lewis for suggesting the turpentine vapour method for extracting thrips.

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NOTES ON A FUNGUS PARASITIC ON GREENHOUSE WHITEFLY

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IN the course of rearing large numbers of *Trialeurodes vaporariorum* (Westw.) for research on its biology, a number of larvae were observed to be attacked by fungi. Two of these fungi were associated with dead whitefly scales: a *Penicillium* sp., recognizable by the long white spore chains growing on branched conidiophores, and *Cladosporium sphaerospermum* Penzig (determined by Dr. M. B. Ellis of the Commonwealth Mycological Institute), characterized by erect brown hyphal tufts growing from the affected scale.

A third fungus covered the scales, pupae, and adults with a fine weft of hyphae (Plate III, 1) bearing capitate conidiophores and its identity as *Cephalosporium aphidicola* Petch was confirmed by Dr. A. H. S. Brown of the C.M.I. As there are small differences in the conidial dimensions between the cultures provided from *Trialeurodes* and dried specimens in the herbarium collections determined by Petch, the culture has been placed under *C. aphidicola* with the reference number IMI 68689.

Horne (1915) described the species *C. lefroyi* from greenhouse whitefly on *Centropogon* at Wisley, but Petch (1941), after examining material from the aphid *Capitophorus fragariae* Theob. on strawberry at Auchencruive, Scotland, placed this name as a synonym of *C. aphidicola*. The only other reference to this fungus on *Trialeurodes* is in Weber's (1931) monograph where Professor Lakon identified it as *Sporotrichum globuliferum* Speg. However, the illustrations in his paper show that the species involved was definitely a *Cephalosporium*.

The first indication that an adult has been attacked by the fungus is the production of large ventral wax bundles on the abdomen (Plate III, 2). Weber (p. 645) figures similar bundles of wax strands, which he attributed to damage to the wax glands in deformed adults emerging from pupae which had experienced a thermal shock treatment (eight days at 40° F followed by 72° F). The adult becomes inert within 12 hours and in three days is invested by a fine weft of mycelium. The characteristic arrangement of conidial heads at right angles to the main hyphal strands, either singly or in whorls of three to five conidiophores, is evident under low magnifications (Plate III, 2). Within the conidial heads the oval conidia, ranging in size from 3·5–5μ by 1–1·5μ are held together in a droplet of mucilage. This drop is readily soluble in water so that spore suspensions for spraying are conveniently obtained. Infected larvae show no visible symptoms until the hyphae appear externally. Pinto-Ganhas (1956) demonstrated that the hyphae grow through the body-wall from conidia germinating on the surface, and eventually fill the body cavity.

Nymphs of the aphid *Pemphigus bursaria* (L.) have recently been observed producing similar strands of wax and showing a very marked thickening of the leg and antennal segments when attacked by *Cephalosporium*.

To test the susceptibility of the various stages of the whitefly to *Cephalosporium*, infested leaves were sprayed with spore suspensions and placed on damp filter paper in sealed 3 × 1 in. tubes. Other infested leaves were sprayed with distilled water as controls. After seven days incubation at 80° F the results in the Table were obtained which suggested that only the eggs and active first instar nymphs were immune.

Tests on Pathogenicity of Cephalosporium aphidicola *to Whitefly*

Developmental Stage	Sprayed with Spore Suspensions			Sprayed with Water only		
	No. Alive	No. Dead	Mortality *Percentage*	No. Alive	No. Dead	Mortality *Percentage*
Adult	28	28	100	30	0	0
Pupae	48	48	100	34	0	0
Instars 2 and 3	61	57	93·4	45	5	11·1
Instar 1	18	0	0	37	2	5·4
Eggs	206	0	0	112	0	0

With a view to exploiting this pathogenic fungus for biological control of greenhouse whitefly, experiments were made to determine the environmental conditions necessary for spore germination. Spore suspensions in water were sprayed on to slides cleaned and prepared by the method of Hart and MacLeod (1955) and then dried in air passed through bacterial filters. The slides were placed in test chambers consisting of petri dishes that had been made air-tight by grinding both sections together with carborundum until a uniform seal was obtained. The humidity in each test chamber was controlled with sulphuric acid to give a range of relative humidity from 97 to 100 per cent. The dishes were incubated at 80° F for three days before examination. The results were:

					Water droplets
Relative humidity. Per cent	97	98	99	100	
Percentage spore germination	10	21	27	31	87

Pinto-Ganhas found a similar dependence of germination on high humidity in *C. lecanii* Zimm, where conidial germination proceeded very quickly in aqueous suspensions.

In greenhouses the humidity is high only for eight to ten hours during the night, and it was therefore of interest to determine how much conidial germination might occur within that period, as, owing to the danger from phytophagous fungi, it would not be practicable to raise the humidity artificially for long periods. Spores were placed in water under a coverslip exposed for various periods at 100 per cent relative humidity and 80° F before assessment of spore germination, which was found to be as follows:

Hours at 100 per cent R.H. and 80° F.	2	4	10	20	24	36
Percentage germination	8	17	32	68	76	84

These results show that as long as 20 hours is necessary before a high proportion of the spores germinate, even under optimum conditions, the economic use of *Cephalosporium* is unlikely to prove practicable. A further difficulty was the rapid loss of virulence through subculturing on Sabouraud's agar thereby necessitating repeated reculturing from infected insects.

I am indebted to Miss B. Gurney for the initial discovery of infected whiteflies and to Mr. J. E. Morton for the photographs.

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EFFECT OF FRIT FLY ON THE DEVELOPMENT OF A LEY

by D. WEBLEY

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THE damage caused to oats by the frit fly, *Oscinella frit* L., is well-known and widespread; less is known, however, about its effect on the establishment of young leys. For instance, the practice of using a cereal nurse crop when reseeding, by providing the pest with another host plant, might complicate and mask the fly's ultimate effect on the resulting ley. For this reason, any study of the effect of this insect on the establishment of young sward must first consider what effect it has on a seeds mixture sown without a nurse crop. Frit readily infests *Lolium* and *Festuca* among the cultivated grasses (Cunliffe, 1923), and it seemed likely that a heavy attack immediately after germination may eliminate some of the sown grasses and make way for the re-establishment of the weeds and less valuable indigenous species of grasses. The attack, therefore, might be manifest not only by a poor ground cover, but also by a less noticeable change in the botanical composition of the resulting sward.

In 1957, a pilot trial was laid down at Crick, Monmouthshire, to assess this damage. The field chosen had been arable for many years and was reseeded without a nurse crop. The seeds mixture, based on 20 lb ryegrass, 4 lb meadow fescue, and 4 lb timothy per acre, was sown on July 24 under good conditions. On July 29, before the grass had appeared above ground level, two areas, each 30 ft × 15 ft were chosen at random and pegged out; half of each area was sprayed with 15 per cent miscible dieldrin at the rate of one-third gallon to 100 gallons water per acre; the same half-plots were sprayed again on August 2 and 9.

Egg and plant counts were made on August 2 and 19, and on September 12 and 19, and details are shown below. The egg counts are the bulked results of ten samples, each of 9 square inches (five from each control plot), taken with the Cardiff sampler (Webley, 1957). The shoot counts are based on the plants from the same samples:

	Aug 2	*Aug 19*	*Sept 12*	*Sept 19*
Eggs	70	84	22	16
Shoots	43	132	54	49

From these figures it appears that the majority of the eggs were laid in the first two weeks when the young seedlings were appearing above ground level.

Visual observations were made weekly, and when it had become apparent that the attack had reached its peak (September 12), thirty plants were removed at random from each plot and dissected in the laboratory. By this time the sprayed plots were well in advance of the unsprayed in leaf length and ground cover. Note was kept of the number of healthy and attacked shoots per plant, and the size of the plants, the results being as follows:

	Sprayed	*Unsprayed*	*Standard Error*
Average leaf length in cm	26·1	20·7	±1·08
Number of attacked shoots per plant	0·23	2·8	±0·10

Both results are significant at the 0·001 probability level (D.F. = 59), but there was no significant difference between the number of shoots per plant (7·5 ± 0·12) in the sprayed and unsprayed plots.

Five months later (January 13) ten 2½-inch cores of the sward were taken at random from each plot, washed free from soil and a count was made of the number of grass and weed plants present. The number of ryegrass plants per 2½-inch core was 6·6 in the sprayed plots and 1·5 in the unsprayed; a difference that is statistically significant at the 0·001 probability level. The sprayed plots were still easily distinguished even though the field had been grazed.

As well as the ryegrass analysis a note was kept of the number of weed species present in all plots. *Veronica chamaedrys* L. was present in both sprayed and unsprayed plots, but more numerously in the unsprayed. *Ranunculus repens* L., *Chrysanthemum leucanthemum* L., *Achillea millefolium* L., *Matricaria maritima subsp. inodora* (L) Clapham, *Crepis spp.* L., *Aphanes arvensis* L., *Myosotis arvensis* (L) Hill, were all present only in the unsprayed plots at the level of one plant per 20 cores.

Of the grasses, *Poa annua* L. was present only in the unsprayed plots (3 out of 20 cores), as also was *Bromus mollis* L. (1 out of 20 cores).

Although the experiment was not a critical one, these results do demonstrate that the frit fly population of a ley can have a profound effect on its establishment and subsequent development, not only by causing bare patches, but also by allowing the coarse grasses to increase at the expense of the ryegrass and fescues.

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CONTROL OF COBWEB DISEASE OF MUSHROOMS

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IN 1957, pentachloronitrobenzene, in the form of a 20 per cent dust, was tried on shelf beds in a mushroom house in Yorkshire where, for the past few years, cropping has been reduced by the prevalence of cobweb disease, *Dactylium dendroides* Fr. The house was purpose-built for mushrooms, with a concrete floor and shelves arranged in three tiers giving an effective cropping area of 1,100 square feet. The compost was made from horse manure and cased with a peat-chalk mixture on April 17, 1957. Three weeks after casing, half the bed area, comprising parts of the top, middle and bottom beds, was dusted with the 20 per cent PCNB dust at the rate of 1 lb per 1,000 square feet. At this time the mushrooms were appearing in the "pin head" stage, and it was just possible to distinguish the dusted beds from the undusted by the slight deposit of the white powder against the dark background of the peat.

Two weeks after dusting, when the first flush of mushrooms was almost cleared from the beds, patches of cobweb disease appeared on the untreated beds, but were absent from those that had been dusted. The patches steadily expanded during the following week, after which the treated beds were given a second dusting at the same rate as before. The effect of the last treatment was to prevent further spread of the fungus along the beds. The patches were spot-treated with at least twice the amount of dust used elsewhere.

During the further cropping period of six weeks, no patches appeared on the treated beds. From the 1,100 square feet of bed, 1,876 lb of saleable mushrooms were produced. This was above average for the nursery as a whole, and in marked contrast to the previous crop from the particular house, which produced less than 300 lb before the disease made further cropping impossible.

Since the experiment, the grower has adopted dusting with PCNB as a routine measure to beds about to crop and the disease has not reappeared. If applied before a flush, and between flushes, there appears to be no retardation of mushroom growth, but on a trial area of bed where the dust was mixed with the casing material before its application to the compost, mycelial growth and mushroom production were almost entirely suppressed.

NEW OR UNCOMMON PLANT DISEASES AND PESTS

A vascular discoloration in horse-radish. At Boughton Heath, Chester, horse-radish is grown for processing, and in 1954 a disorder causing some concern was reported by Mr. E. C. Herwin. During processing the roots are ground to a thick viscous white fluid, and it had been found that a black vascular staining was present in some roots which discoloured this fluid so that it was commercially unacceptable. During 1954, and again in 1956, specimens of affected roots were examined and isolations were made but these failed to reveal the presence of any bacterial or fungal pathogen. The disorder is almost certainly not that reported by T. H. Middleton in 1909, when *Pseudomonas campestris* was considered to be the cause of severe infections over a number of seasons in the Altrincham area of Cheshire. In the horse-radish cultivation, lateral roots (thongs) are planted vertically in dibble holes in March or April, and by secondary thickening, these thongs develop into the required product by October or November. The secondary thickening differs from that of a normal exarch dicotylenous root only in that tertiary vascular bundles are differentiated in the storage parenchyma of the secondary xylem. New lateral roots grow from the crown of the rootstock and are the thongs for the next season. When discoloured and apparently healthy thongs were planted at Wolverhampton in 1957 all the resulting lateral roots produced were free of the disorder. All the secondarily thickened roots from clean stock were unaffected, but 60 per cent of those originally affected were still affected at lifting. The problem appears to involve some factor other than a pathogenic organism.

W. R. ROSSER

Onion smut in Northern Ireland. Onion smut, caused by *Urocystis cepulae* Frost, was recorded in July 1951 on young onion plants being grown by a plot holder in Londonderry. This appears to be the first record of the occurrence of onion smut in Northern Ireland. No further record of the occurrence of the disease has since been registered. Specimens have been preserved in the Herbarium of the Department of Mycology and Plant Pathology, The Queen's University, Belfast (Herbarium No. 55/51).

A. E. MUSKETT

***Tephritis conjuncta* on Chrysanthemums in Scotland.** Niblett (*Ent. Rec.*, 1947, **59**, 28–32) lists the larvae of *Tephritis conjuncta* Lw. in the flower heads of *Chrysanthemum leucanthemum* from N.E. Surrey, but no other records from Britain appear to have been published. Records at the Plant Pathology Laboratory, Harpenden, refer to the species doing considerable damage to the heads of *C. maximum* and *C. leucanthemum* at Trawscoed, Aberystwyth, in 1951, and adults were reared at Harpenden from damaged material received from Northumberland in the same year. In July 1956 I received several heads of *C. maximum* (var. Esther Read) from Brodie, Morayshire, which were distorted due to larval feeding at the base of the florets and on the surface of the receptacle. Usually two larvae were present in each flower, and pupation within the capitulum was complete in caged material by July 28, the adults commencing to emerge during the middle of August. I thank Mr. H. Oldroyd, British Museum (Natural History), for identifying the adult *T. conjuncta*.

M. W. SHAW

Verticillium Wilt of Apple. In the spring of 1955, two- and three-year-old branches of Cox's Orange Pippin, from a twenty-year old, ten acre orchard near Canterbury, were received at East Malling Research Station. There was death of several blossom trusses, closely resembling that due to Blossom Wilt (*Sclerotinia laxa* Aderh. & Ruhl.) and sectorial discoloration of the wood. *Verticillium* was isolated from the stained wood of both branches and spurs. In the two years that this isolate has been retained in culture it has produced only the black resting mycelium typical of *V. albo-atrum* Reinke & Berth. Later in 1955, when the orchard was inspected, a total of six Cox's (on M. IX rootstocks) were noted with dead spurs on otherwise healthy branches. All branches carrying dead spurs and a few apparently unaffected branches from the same trees, showed greyish-brown discoloured sectors in the outer wood, but no further isolations were attempted. No recurrence of spur death in the orchard was reported by the N.A.A.S. officers in 1956 and 1957. Typical vascular discoloration, but no wilting, occurred when branches of potted, three-year-old Cox trees were inoculated with the isolate from this orchard and kept out of doors. Although *V. albo-atrum* is recorded as attacking a wide range of woody hosts (Engelhard, A. W., *Plant Dis. Reptr.*, 1957, *Suppl.* 244) including apricot, peach, plum and cherry, there appears to be only one previous record, from Bulgaria, of infection of apple (Atanasoff, D. *et al*, 1932, *Rev. appl. Mycol.*, **11**, 745–6).

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Greasy Blotch of Carnation. During the winter of 1956–7, greasy blotch of carnation, caused by *Zygophiala jamaicensis* Mason, was noticed on three nurseries in the Lea Valley and Bedfordshire. The disease shows small patches composed of fibrillate patterns, which are clearly seen on the edge of the patch or in the early stages of infection (Plate II, 2, 3). The patches are shiny green owing to the removal of the waxy bloom from the surface of the leaf. In severe attacks the whole leaf may lose its bloom and become shiny green. The fungus is present as a scanty superficial mycelium bearing characteristic dark twisted conidiophores (Plate II, 1). According to the carnation growers, severely affected cuttings root very slowly and poorly, and foliage on plants in the flowering beds dies prematurely. The fungus was first described by Martyn (*Commonwealth mycol. Inst., Mycol. Paper* 13, 1945) on banana, and the disease on carnations was described by Baker and Davis (*Phytopathology*, 1953, **43**, 585) from California. The latter state that the disease is serious only during periods of high humidity, and this agrees with observations here. The present record appears to be the first of the fungus and of the disease in England. The photographs were taken by Mr. H. Wheeler.

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